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TUCSON WASTEWATER RECLAMATION PROJECT
AT TUCSON, ARIZONA

Frank Brooks

Tucson Water and Sewers Department
Tucson, Arizona

May 1968

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ANNUAL PROGRESS REPORT
1967 - 1968
TUCSON WASTEWATER RECLAMATION PROJECT

at

TUCSON, ARIZONA

MAY 1968

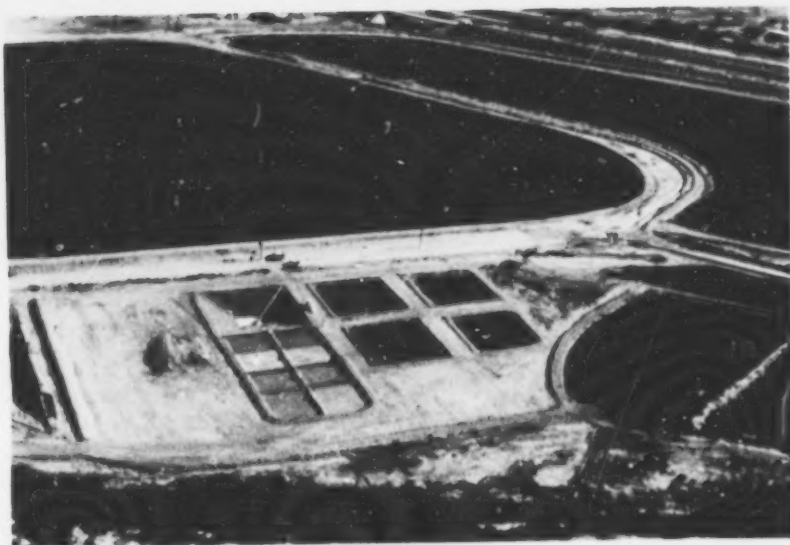
PREPARED FOR
THE FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
WASHINGTON, D.C.

PLANNING & RESEARCH SECTION
WATER AND SEWERS DEPARTMENT
CITY OF TUCSON
CO-OPERATING WITH
DEPT OF CIVIL ENGINEERING, DEPT. OF
MICROBIOLOGY, AND COOPERATIVE
FISHERIES UNIT, UNIVERSITY OF ARIZONA

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FEDERAL WATER POLLUTION CONTROL ADMINISTRATION



TUCSON WASTEWATER RECLAMATION PROJECT

Six Spreading Basins With Collection Trough

Four Test Fish Ponds To The Right

42-Acre Holding Lake Above

C I T Y O F T U C S O N

WATER AND SEWAGE SYSTEMS
City Hall Tower
69 N. Meyer Ave.
P. O. Box 5077
Tucson, Arizona 85703

May 17, 1968

Riley N. Kinman, Ph. D.
Chief, Demonstration Grants Branch
Division of Grants Management, FWPCA
U. S. Department of Interior
Washington, D. C. 20242

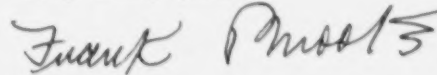
Dear Dr. Kinman:

In compliance with Water Pollution Control Demonstration Project Grant No. WPD-108-03-67, dated May 24, 1967, awarded to the City of Tucson, Arizona, Department of Water & Sewers, we are pleased to submit herewith the progress report for 1967-68 of the Tucson Wastewater Reclamation Project. This report contains tables, graphs, drawings and other pertinent data, along with a summary of the work produced during the past year.

As mentioned in the report, detailed studies of particular phases, such as filter hydraulics, are underway and will be reported upon subsequently.

We wish to thank you for your continuing cooperation and financial support in our wastewater reclamation effort.

Very truly yours,



Frank Brooks, Director
Department of Water & Sewers

FB:GED:ps

Encl: Progress Report

SUMMARY

This report summarizes the work actually performed since the completion of the Pilot Filter facility in June of 1966 to April of 1968.

The project scope for the period required the participation of the University of Arizona (Department of Sanitary Engineering, Department of Microbiology and Medical Technology, and Cooperative Fisheries Unit), and the City of Tucson, the grantee.

The Planning and Research Section, Department of Water & Sewers, City of Tucson logged and interpreted data acquired from the project pilot filter, project area wells, and coordinated the activities incident to filter modification, scheduling of construction work, supervision of equipment purchases, and assignment of itineraries as related to sampling programs. In addition: the formulation, production, and execution of plans, maps, and forms utilized in project reports, data accumulations, and ancillary activities, as well as preparation of plans and schemes for alternative methods of wastewater reclamation. All chemical analyses were conducted by the Project Chemist, who also assisted materially in all other aspects of project activities and particularly in report preparation.

The Department of Sanitary Engineering performed all bacteriological tests, experimental fish pond productivity studies, dye studies, and assisted in the sanitary survey of project wells and provided physical assistance in the accumulation of samples for project participants. Additional services were performed in the matter of filter activity scheduling.

The Microbiology and Medical Technology Department advised on project activities and the virus test program. At the same time, continuing research was accomplished into the current methodologies for the isolation of virus particles and new methods of virus isolation were under study

with those preliminary schemes for isolation already accomplished.

The Technical Committee reviewed, discussed, and acted upon all Project plans, proposals, and deviations, as well as the technical aspects that arose from time to time.

The present report includes assimilation, interpretation, graphic reproduction, tabulation, and re-evaluation by the Planning and Research Section of the City of Tucson, in cooperation with the Project Chemist.

The phases of this report may be simply divided into I, II, III and IV. In order, they are Bay #1 loading (longest intra-filter travel distance), Bay #3 loading (intermediate travel distance), Bay #4 with vertical pumpage (shortest travel, both horizontally and vertically), and Bay #3 repeat after surface rejuvenation.

The data available from the participating agencies as reproduced, and/or analysed, is included elsewhere in this report. The accumulation and interpretation of this data, based on intra-filter travel distance, is a factor in the prediction and production of a suitable tertiary water for future use. The concentrations of such pollutants as B.O.D., ammonia nitrogen, nitrate, C.O.D., phosphate, virus, and algae may be thereby controlled. Completion of the sanitary well survey pointed up the need for a vigorous program in well maintenance and a controlled application of secondary sewage effluent to irrigated fields in the neighborhood of domestic wells. Virus studies have resulted in more sensitive methods for their isolation and identification. Means and methods for surface renovation of inefficient Bays, due to prolonged application of high nutrient Pilot Filter Influent (PFI), are being considered at this writing.

Most of all the tenor of the Project has become anticipatory with the contemplated construction of a Project Production Filter, recreational lakes, a fish hatchery and a source of water for inclusion in a declining water table.

Future quarterly reports will reflect the advance towards the completion of Project Objectives.

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CHAPTER I
INTRODUCTION

1. PHILOSOPHY

A. Tucson, Arizona and its immediate environs are well situated climatically to enjoy all the benefits that naturally accrue to those populated areas of the earth that find themselves in a rainpoor desert clime. However, the present state of our plight is one that developed quite rapidly from the result of a population and agricultural explosion over the past twenty years, into such a desirable region.

In general, the mass of ancient water, which lies within the Tucson basin and the previously unlimited water source that inhabits the depths of an ephemeral stream known as the Santa Cruz River has suffered tremendously as far as volume available and depth to water. Further, as wells are deepened and pumpage increases, it is apparent that another source other than that presently in existence, should be found.

The metropolitan population of the City of Tucson, both domestic and industrial, creates in excess of twenty-five MGD on the average of secondary sewage effluent and, while seventy-five percent of this material is utilized on a contract basis for agricultural irrigation, there still remains at this writing, upwards of eleven million gallons per day as a source of water for public recreational facilities as well as ground water recharge. Being an arid region, the re-use of this water would do much to supplant the dwindling supply of native

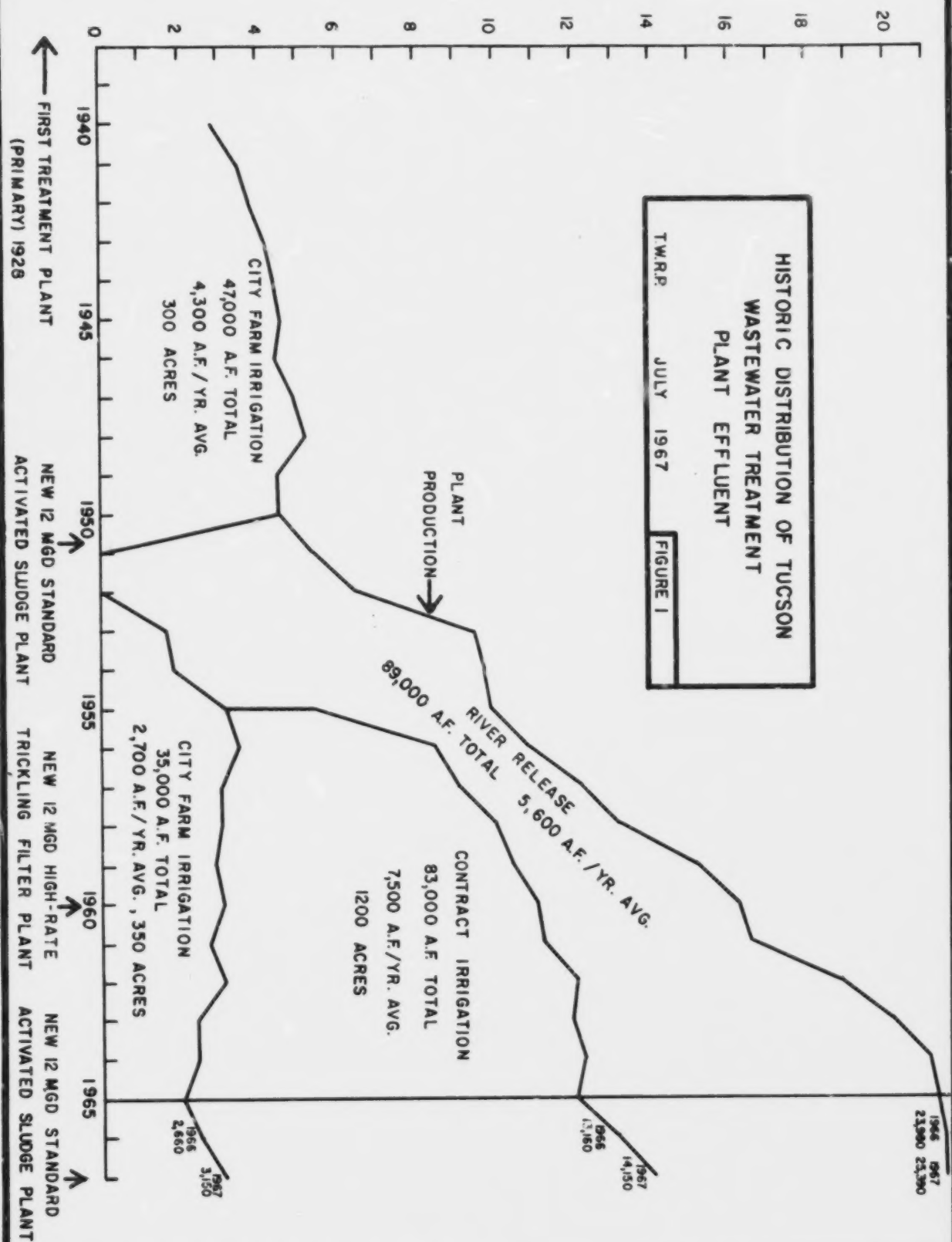
TABLE 1
HISTORIC TUCSON WASTEWATER TREATMENT
PLANT EFFLUENT DISTRIBUTION 1940-67
(Acre-Feet)

Year	TWTP Effluent	City Farm Irrigation	TWTP Grounds Irrigation	Contract Irrigation (Est.)	River Release (Est.)
1940	2,820	2,820			} Estimated Maximum 5% Of Annual Production
1941	3,450	3,450			
1942	3,770	3,770			
1943	4,220	4,220			
1944	4,460	4,460			
1945	4,620	4,620			
1946	4,410	4,410			
1947	4,950	4,950			
1948	5,190	5,190			
1949	4,500	4,500			
1950	4,570	4,570			
1951	5,320	0			5,320
1952	6,530	0	10		6,520
1953	9,530	* 1,680	20		7,830
1954	9,720	1,850	20		7,850
1955	9,950	3,230	30	** 2,170	4,520
1956	10,870	3,550	20	5,000	2,300
1957	12,290	3,040	50	6,000	3,200
1958	13,280	3,070	90	7,000	3,120
1959	15,170	2,940	70	7,500	4,660
1960	16,280	3,100	60	8,000	5,120
1961	16,650	2,740	70	8,500	5,340
1962	18,910	3,120	80	9,000	6,710
1963	20,190	2,310	130	9,500	8,250
1964	21,150	2,320	110	10,000	8,720
1965	21,300	2,010	130	10,000	9,160
1966	23,980	2,660	150	10,500	10,670
1967	25,390	3,150	150	11,000	11,090

* 1953 Lease of City Farm.

** 1955 Contract Sale of Surplus Effluent.

THOUSANDS OF ACRE-FEET PER YEAR



waters and at the same time, demonstrate to the public the aesthetic acceptability of such waters when properly reclaimed and under constant surveillance for chemical, bacterial and viral pollutants by agencies of competent jurisdiction.

B. CITY OF TUCSON

As early as Spring of 1964, the Planning and Research Section, Department of Water & Sewers, City of Tucson, produced a feasibility study that resulted in the immediate appropriation of \$150,000 by the Mayor and Council, for the construction of a tertiary treatment system to supply renovated secondary sewage effluent for a series of recreational lakes to be utilized for public fishing, boating and eventual swimming after public health approval of the water in question. The ground work for this project was executed by a panel of experts including parties from the Planning and Research Section of the City of Tucson, University of Arizona Sanitary Engineering Department and Department of Microbiology (Virology), and other individuals with staff and research experience in the field of wastewater reclamation. However, the appropriation fiscal time limit expired as a result of failure to act and the project director chose to re-evaluate the work done by other researchers and thus the Tucson Wastewater Reclamation Study evolved as a Demonstration Grant awarded by the U.S.P.H.S. in June of 1965.

C. FEDERAL

Shortly following the Grant award, the United States Department of the Interior, Federal Water Pollution Control Administration took over the responsibilities of furthering the administrative

management of all U.S.P.H.S. Demonstration Grants and Studies, and thus was born the relationship which exists today. This realignment proved most beneficent to the City of Tucson and its associated participants. The Federal Water Pollution Control Administration has urged, supported, and cooperated with our initial efforts in getting the Study underway and has proved time and again its willingness to flex, as new and sometimes unusual operational activities were being formulated and integrated into what shortly became TWRP, the Tucson Wastewater Reclamation Project.

Antedating this program by some months, was the realization by the Federal government that the pollution of surface and ground waters had reached the stage of an emergency within the United States. As a result, over three billion (3,000,000,000) dollars was budgeted by the Congress to provide the wherewithal for research and aid-in-construction to individuals, corporations, cities, counties and states to abate the impending disaster. For the City of Tucson, this aid has brought us to the doorstep of a production tertiary filter and a wealth of research information, which will now be put to practical use in the coming months.

2. HISTORY

The City of Tucson, Planning and Research Section, Department of Water and Sewers, submitted a proposal in April of 1965 to construct an anaerobic pilot filter, four experimental fish ponds and with the University of Arizona Departments of Sanitary Engineering and Microbiology, demonstrate the feasibility of upgrading secondary activated

sludge effluent applied to that pilot filter by means of a series of chemical, bacteriological, and virological tests to be conducted by the City of Tucson chemist, and the participating agencies of the University. A Technical Planning Committee was established to guide the project. The final stage of the project proposed to build an anaerobic production filter to supply a series of four recreation lakes whose effluent waters would be used to recharge the declining water tables in the Tucson Basin. Since secondary sewage effluent was being continually used to irrigate farm lands downstream from the Tucson Wastewater Treatment Plant, the effect on the ground water of this continuous application would be of interest. Therefore, the Pima County Health Department and the Arizona State Health Department became an integral part of the project as well as the Arizona Fish and Game Commission who were interested in the possibility of additional water for recreational purposes.

Soon after the Demonstration Grant award in June of 1965, work commenced on the vertical horizontal anaerobic earthen pilot filter. Field quality control worked closely with construction and the first secondary activated sludge effluent filled a completed filter in June of 1966.

3. PROJECT PERSONNEL

A. Present

<u>Project Position</u>	<u>Name and Title</u>
Director 1968 -	Frank Brooks, Director Department of Water & Sewers City of Tucson
Director 1965 - 67	Paul Beermann, Director (Resigned) Department of Water & Sewers City of Tucson

<u>Project Position</u>	<u>Name and Title</u>
Sanitary Engineer 1965 - 68	Quentin M. Mees, Professor Department of Civil Engineering University of Arizona
Virologist 1967 - 68	Wayburn S. Jeter, Ph. D. Professor & Acting Head Department of Microbiology University of Arizona
Virologist 1965 - 67	Kenneth F. Wartman, Ph. D., (Deceased) Professor and Head, Department of Microbiology and Medical Technology University of Arizona
Research Biologist (Fisheries) 1966 - 68	Charles D. Ziebell, M.S., Lecturer Department of Zoology Assistant Unit Leader, Arizona Cooperative Fishery Unit University of Arizona
Engineer or Supervisor 1965 - 68	Gordon E. Davis, P.E. Head Planning & Research Section Department of Water & Sewers City of Tucson
Research Virologist 1965 - 68	Peter P. Ludevici, Ph. D. Associate Professor Department of Microbiology University of Arizona
Sanitary Microbiologist 1965 - 68	Robert A. Phillips, Ph. D. Associate Professor Department of Civil Engineering University of Arizona
Research Chemist 1965 - 68	John F. Stafford, A.B. Project Chemist Tucson Wastewater Reclamation Project City of Tucson
Chemist 1965 - 68	Everett J. Trueblood, B.S. Chief Chemist Department of Water & Sewers Sewerage Division City of Tucson
Research Assistant (Virology)	Margaret Bilson, B.S. Department of Microbiology University of Arizona

<u>Project Position</u>	<u>Name and Title</u>
Research Assistant (Virology)	Marion Moore, M.S. Department of Microbiology University of Arizona
Research Assistant (Fisheries)	Robert Hallock, B.S. Cooperative Fisheries Unit University of Arizona
Research Technician (Sanitary Microbiology)	Matts A. Myhrman, M.S. Department of Civil Engineering University of Arizona
Chief Operator	Ernest Fulton, Chief Operator Tucson Wastewater Reclamation Project City of Tucson
Laboratory Preparator (Virology)	Dorothy McKenrick Department of Microbiology University of Arizona
Engineering Aide	Daniel B. Lowe, Jr. Planning & Research Section Department of Water & Sewers City of Tucson

B. Past Personnel

<u>Project Position</u>	<u>Name and Title</u>
Microbiologist 1965 - 67	Dr. Jaime Mendiola, M.D. Visiting Researcher University of Guadalupe, Mexico
Chief Operator 1965 - 67	David R. Tanner, Diplomat Tucson Wastewater Reclamation Project City of Tucson
Research Assistant 1965 - 67	Robert Wills, B.S. Graduate Assistant - Civil Engineering University of Arizona
Assistant to Planning Engineer 1965 - 68	Carl R. Nelson Asst. Planning Engineer Planning & Research Section Water & Sewage System City of Tucson
Technical Advisor 1965 - 66 Field Operations Supr. 1966 - 67	E. O. Dye, B.S. Superintendent Sewage System City of Tucson

Project Position

Name and Title

Virologist
1965 - 66

Robert J. Janssen, Ph. D.
Assistant Professor
Department of Microbiology and
Medical Technology
University of Arizona

Research Assistant
1965 - 67

Alexandera Hodge
Department of Microbiology and
Medical Technology
University of Arizona

Engineering Aide
1966

Walter T. Stein, M.S.
Department of Water & Sewers
City of Tucson

Engineering Aide
1965 - 66

Emilio Fernandez
Department of Water & Sewers
City of Tucson

C. Technical Planning Committee (TWRP)

Edmund C. Garthe, C.E., M.P.M.,
Director of Division of Environmental Health
Arizona State Department of Health, Chairman

Quentin M. Mees, M.S., P.E.
Professor, Department of Civil Engineering
University of Arizona

Wayburn S. Jeter, Ph. D.,
Professor and Acting Head, Department of Microbiology and
Medical Technology
University of Arizona

Fredrick J. Brady, M.D.
Director, Pima County Health Department

Gerry Hauer
Products Manager, Infilco, Inc.
Tucson, Arizona

Charles D. Ziebell, M.S.
Cooperative Fisheries Unit
University of Arizona

Frank Brooks, Director
Department of Water & Sewers
City of Tucson

4. ACKNOWLEDGEMENTS

The report wishes to acknowledge the aid and consultation of Donald R. Anderson, Consultant, who was quick to point out areas of need as Project activities impinged on loci foreign to its capability. The Technical Planning Committee is to be commended for their cooperative guidance and desire to forward the aims of the Project. E. J. Trueblood, Chief Chemist of the Tucson Wastewater Reclamation Plant, provided historical data from his activity and his additional information from the field of sewage chemistry, eased the duties of the Project Chemist.

To suffer so great a loss in the passing of Kenneth Wertmann, is not within the scope of this report to commemorate adequately. Suffice is to say, we have missed his original thinking and our steps are made more difficult by his absence.

Mr. Robert Wills, Mr. David Tanner and others will be remembered by all and the staff of the Engineering Section, Department of Water and Sewers has made the journey much more meaningful.

Special thanks are due Adah Move, Jane Taeger, Madine Tobol and Phyllis Stender for the hours of typing and cooperation in preparation of Project reports.

CHAPTER II

PILOT FILTER

1. DESCRIPTION

The Pilot Filter began as a rectangular excavation of sloping two to one sides, three times as long as wide (300' x 100'), and overall depth of twenty feet. It was designed to provide vertical-horizontal flow in a completely isolated trenching. (See Pilot Filter Plan and elevation appended to report.) At the completion of the excavation, 10 mil plastic sheeting was applied on sides and bottom, over a compacted one-foot depth of silt, joints were plastic-taped, and the back filling with naturally occurring river wash materials was begun.

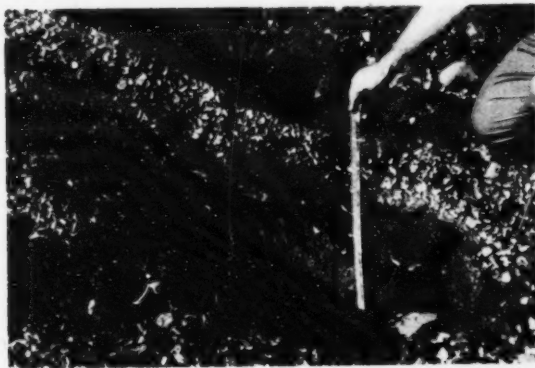
To control the quality of filter media materials placed in the excavation, in-the-field mechanical analyses for grain size was carried out on every batch of material to be spread, and continuing visual inspection was made to rule out accidental inclusion of any silty lens formations which might occur in the carryall pickups. Field permeability studies were run on source areas of the material and quality of test determined acceptance or rejection of media.

Before the filter media was placed in the filter, sampling manholes were set at regular intervals within the excavation on concrete donuts which were back filled internally with large gravel to allow for underdraining water from internal lines during flushing operations. Plastic lining (external) sealed the five (5) foot diameter, twenty-four (24) foot high corrugated metal pipe (CMP) perched on each donut. The CMP's had previously been tapped appropriately to receive the 3/4 inch PVC transmission pipes originating from 2-inch, perforated,

collection pipes encased in gravel at regular distances from each CMP; and lying within the filter media at varying horizons on three, six, nine, twelve, fifteen, and eighteen foot levels; and perpendicular to the long axis of the Pilot Filter. All sampling lines above the twelve (12) foot level were either long or short to sample the peripheral and central flows.

One end (north) of the filter bears a rock facing at two to one slope and ends upon a concrete slab (6') with a collection trough approximately twenty (20) feet long by ten (10) inches in width for the accumulation of tertiary waters, which in turn empty into a concrete collection basin of about 20x10x3 feet with sloping walls. Within this basin, a sump arrangement allows for the intermittent evacuation of water by means of a centrifugal pump, and thereafter, distribution to four experimental fish ponds. On-off operation was under control of liquid-level electrodes. Later, modifications in the number one, two, and three CMP's allowed for vertical pumpage from beneath each basin in question depending upon what level needed this manipulation. A lift pump, liquid-level control, piping, and metering allowed automatic operation. In order to accumulate water at the bottom of the wells when desired lines were open, a temporary concrete seal of the underdrain surface was effected.

At a few feet east of the Pilot Filter, four (4) experimental fish ponds were constructed, whose dimensions were 100 x 100 feet and approximately four (4) feet deep. Ponds were made accessible by gently sloping walls and silt and bentonite provided enough sealing to reduce infiltration losses to about six gallons per minute.



TOP GRAVEL AND SAND BED
Pilot Filter Showing
Thickness Of Organic Buildup



FILTER IN OPERATION
All Basins Flooded
Four C.M.P.'s With
Water Level Recorders

Each north and south pond pair are interconnected to flow from south to north and thence to effluent in a ditch which empties into an ephemeral stream. Tertiary water from the Pilot Filter operation is piped directly to the ponds on an equal and individual basis. (To date, only the southerly pair receives water which in turn flows from south to north into the northerly pair.) Studies are able to be accomplished, then, on the basis of pond detentions of the recovered tertiary water from the Pilot Filter.

Last, and by no means least, was the problem of obtaining secondary activated sludge effluent from a wastewater treatment plant, one mile to the south of the project. To accomplish this, irrigation pumps, outfall lines, a concrete ditch and ancillary pumping facilities delivered the effluent from the Tucson Wastewater Treatment Plant to the Project Pilot Filter by a circuitous two-mile path used to deliver irrigation water to city farms. This arrangement was necessary to separate the trickling filter effluent from the activated sludge effluent which are delivered to a forty-two acre holding pond in a common outfall line.

Meters were installed and monitored on six (6) different locations including assimilation, transmission, and collection points within the Project activity.

Hydraulic heads and surface levels of incoming waters (PFI) on the filter and in the filter were measured by continuous water level recorders installed on standpipes adjacent to each CMP.

2. TESTING PROGRAM

A. Basic Considerations: The past and recent literature on the tertiary treatment of sewage effluent by sand filtration, earthen filters, grassland spreading, et cetera, is voluminous. However, this project has many innovations not found elsewhere in the project industry.

(1) Chemical - First: The theory of conditioning of wastewater by means of confined vertical-horizontal flow has not been thoroughly examined. It is not an uncommon practice to waste water on an open basin, trench or holding pond, only to have all the attendant evils of indiscriminate aerobic conversion of nitrogenous elements present themselves at the ground water table. Now to control the nitrogen spectra is a real challenge. Second: The permeability and use of naturally occurring indigenous filter materials as a suitable source of purification material has not been fully explored.

From the standpoint of chemical purification, the theory to be investigated was what effect tertiary treatment would have on the reduction of nitrogenous substances, detergents, and bio nutrients (such as PO_4). Further, what form of nitrogenous conversion would be acceptable as indicating a reduction in polluting elements, and also, what criteria might be established as minimum standard for acceptance by not only the public health authorities, but the general public as well. The latter facet could be tested by building recreational lakes, boating and fishing facilities.

(2) Bacteriological - Much is known about the aerobic oxidation of polluting substances in secondary sewage effluent, but there is not too much information available on the anaerobic treatment of effluent waters. It was thought best to devise more meaningful methods of analysis and determine what were the organisms responsible for apparent dehydrogenation of ammoniacal constituents of effluents subjected to anaerobic filtration. Also, to investigate the possibilities of denitrification, if this could be observed.

(3) Virological - Several accepted methods are presently in use to isolate virus materials from water. The more common methods are, of course, the gauze pad technique and the multiple millipore membrane method. Both methods are used in isolating virus from waste waters; but each has its own limitations, either on a quantitative or qualitative basis. Two additional methods are being investigated. The aluminum hydroxide method, based on the precipitation of virus particles from a known quantity of solution, appears to have not only the ability to retrieve almost one hundred percentum of the available virus; but reduces the time involved in such procedures. The antigen-antibody phenomenon as applied to various fish species abiding in polluted waters, promises even more delicate means for the detection of virus in pilot filter effluent waters. The significance of the new methodologies will certainly cause some reassessment of previous studies on virus infestation of wastewaters in the light of the possibility that the previous recovery methods may be deficient.

B. Technical Guidance: In order to continually monitor project objectives and philosophies, a Technical Planning Committee was impaneled to meet at regular intervals or on special call to determine the needs of that project on a technical basis. From time to time, as roadblocks, deviations, or major changes in emphasis occurred, the Committee gave of their combined opinions so that an end result, within the guidelines, might be realized.

C. Phased Operations:

(1) Pilot Filter, Phase I - During this period, maximum vertical horizontal travel distance was utilized to test the theory that it was more efficient than a shorter travel distance, e. g., measure the degree to which common pollutants, such as: B.O.D., ammonia, phosphate, ABS, nitrate, etc., would be diminished or totally excluded. Bay #1 was therefore subjected to alternate day loadings of approximately 45,000 gallons of secondary sewage effluent with an average recoverable effluent of 17,700 gallons per day at the effluent end. During this period, some 3-1/3 million gallons were applied. The applied waters had to travel an average of 250 feet to exit. (See Table #1 of Hydraulics Chapter)

(2) Pilot Filter, Phase II - Bay #3 was activated as a spreading area and the travel distance was approximately halved by this activity. The effective volume of water traversing the filter was approximately 2-1/2 times the previous loading, and therefore, effluent amounts were more than doubled on a daily basis comparison. Intra-filter observations of water quality were continually monitored with

depth and distance traveled as a comparison to incoming and effluent water. Dye studies were instituted to determine detention time, arrival times, and short-circuiting phenomena. During the period, careful checks of infiltration rates were accomplished to determine plugging of filter surface and the hydraulic head of the internal sampling ports was measured to establish factors relating to filter media saturation, and therefore, subsurface subatmospheric conditions.

- (3) Pilot Filter, Phase III - Operationwise, this phase constituted a major deviation and the filter sampling wells were equipped to produce effluent from a purely vertical activity with combined pumping volumes in excess of 30,000 GPD and total filter effluent volume from a vertical horizontal + vertical Bay #4 operation of more than 140,000 GPD. The vertical part was executed by means of opening the lowest lines (18 feet from surface) and pumping intermittently to collection ponds. Thus, one-fourth (1/4) of the PFE during this period was derived from a purely vertical pumpage.

During the period, a severe diminution of effluent volume occurred as a result of rapid sealing of the pilot filter surface to a depth of some 15 centimeters by a blackish brown organic mass of tarry consistency, and not only prevalent in the interstitial spaces of the filter gravel cover, but as a homegenous mass throughout the surface of the filter media. (See photograph)

- (4) Pilot Filter, Phase IV - This period of operation repeats the previous Bay #3 operation on a reworked basin surface. Attempts were made to duplicate the initial Bay #3 as regards volume of waters derived from this operation, quality of water, and at the same time, to study the effect of certain physical treatment of the Bay surface as a method of re-establishing the earlier infiltration efficiencies. A certain amount of vertical pumpage was done in order to guarantee the dryness of media in Bay #1 for removal and replacement.

D. Surface Rejuvenation: It is a fact that a filtering surface, receiving X number of gallons of contaminated fluids over a period of Y months, weeks, days or even hours, eventually loses its infiltration properties. We are concerned at this instant, with the rehabilitation of the surfaces. Naturally, some questions should be answered in regard to this problem.

- (1) What is the nature of the plugging substance?
- (2) From what source is it constituted?
- (3) Is the material accumulation transient or permanent?
- (4) Can it be removed in situ by any means?
- (5) What methods can be utilized to minimize this accumulation?
- (6) What steps should be taken to rehabilitate the surfaces and therefore, increase percolation?
- (7) Does the surface material contribute to the plugging?

This list could be lengthened, but the basic problem to solve is still, rejuvenation of a plugged surface by the means available. Studies of surface rehabilitation are underway and will be available in the period following this report.

CHAPTER III

HYDRAULICS

1. FILTER LOADING

Description of the principal phases (I through IV) of filter operation has been given in the preceeding chapter. However, intervening periods of filter revamping or alteration and short term experimentation are also included in Table 1.

During the period July 1966 through April 1968, a total of approximately 30 million gallons of activated sludge secondary effluent was applied to the Pilot Filter Spreading Bays and a metered total of 27 million gallons of tertiary treated effluent was passed through the Pilot Filter. This apparent loss of approximately 10% of applied water can be attributed to evaporation, spillage and difficulty of meter maintenance.

Daily documentation of these activities are shown on Plates 1 through 8, which attest to the variations in loading activity. Daily extremes of wastewater applied range from a high of nearly 200,000 gallons to a low of 13,000 gallons to nothing at all on many days during the operating period.

2. FILTER PRODUCTION

Initial output of the Pilot Filter is a direct function of the hydraulic head available depending upon the spreading bay utilized and the percolation rate as governed by the filter media. Very shortly, after initiation of a given cycle of operation based on continuous inundation of the spreading bay surface, the production is observed to drop as a result of diminution of the infiltration rate at the

TABLE 1
T W R P
PILLOT FILTER HYDRAULIC DATA
FOR 2ND & 3RD YEAR OPERATIONS, JULY 1966-APRIL 1968
(GALLONS PER DAY)

OPERATIONS PERFORMED	INCLUSIVE DATES	PERIOD IN DAYS	TOTAL INFLUENT	AVERAGE DAILY INFLUENT	DAILY EXTREMES INFLUENT		TOTAL EFFLUENT	AVERAGE DAILY EFFLUENT	DAILY EXTREMES EFFLUENT	
					HIGH	LOW			HIGH	LOW
1. Filter Conditioning	7-7-66 - 8-7-66	32	1,986,860	62,100	261,000	68,300	1,341,800	41,900	92,000	2,800
2. Bay #1 (Phase 1)	8-8-66 - 1-4-67	149	3,359,420	22,500	115,600	13,600	2,630,300	17,700	29,100	12,700
3. Bay #3 (Phase 2)	1-5-67 - 4-11-67	96	4,569,600	47,600	93,400	28,400	3,923,420	40,900	50,000	31,100
4. Filter Rinsing and Vertical	4-12-67 - 5-20-67	49	1,354,100	27,640	158,000	26,000	905,790	18,500	34,850	5,000
5. Bay #4 and Vertical (Phase 3)	5-31-67 - 10-6-67	129	12,419,700	96,300	190,400	30,100	5,486,320	42,600	88,550	19,000
6. Bay #3 and Vertical (Filter Alteration)	10-7-67 - 11-5-67	30	1,095,900	36,500	118,700	42,800	372,700	12,400	19,500	9,900
7. Bay #4 and Vertical (2nd Trial)	11-6-67 - 12-4-67	29	1,367,300	47,100	160,000	52,800	689,600	23,100	39,800	20,000
8. Bay #3 and Vertical (Phase 4)	12-5-67 - 4-10-68	126	3,476,000	30,300	104,000	26,600	2,880,940	22,500	33,800	16,000
9. Bay #1 (2nd Trial)	4-11-68 - (continuing)	5	240,000	48,000	100,000	60,000	103,700	20,740	22,500	17,300

surface. This reduction in production rate for the four principal operating phases is shown in Figure 1. Most dramatic is the decline of Phase III (Bay #4) production which ranged from 72,000 GPD to 24,000 GPD in 3-1/2 months of continuous operation. All operational phases exhibited a similar downward trend. Comparison of the Phase II and Phase IV (Bay #3) ranges of effluent production demonstrate the effect of soil clogging. The initial production of Bay #3 - Phase II operation was about 50,000 GPD, which dropped off to 35,000 GPD during the 3-1/2 month operating period. By comparison, however, the initial production of Bay #3 - Phase IV operation was only 28,000 GPD, reducing to 21,000 GPD during a comparable period. Details of the effluent production are shown on Plates 1 through 8 and Summary data is included in Table 1.

3. INFILTRATION RATES

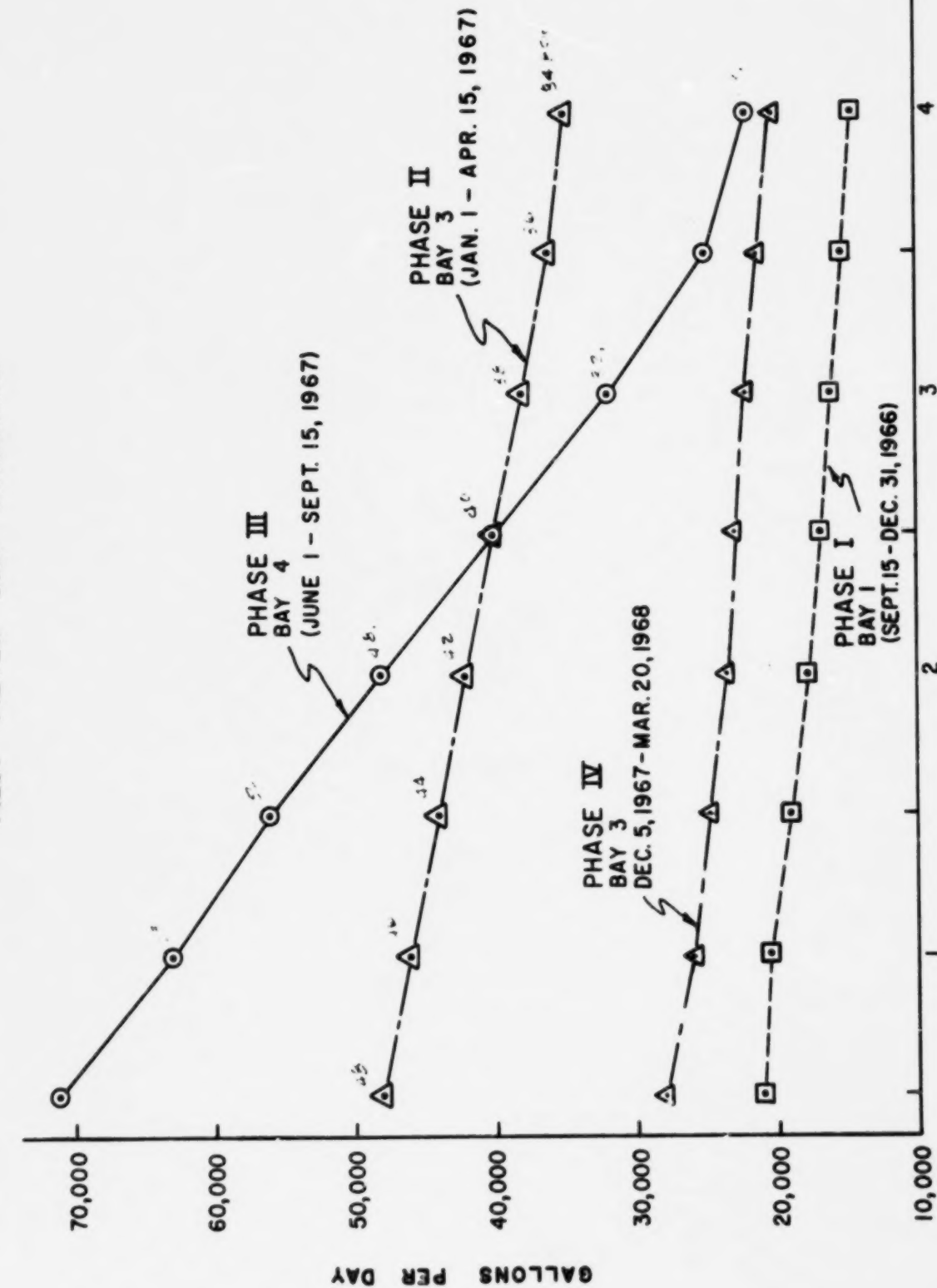
Throughout the investigation period, filter production from a particular bay loading was observed to decline gradually or drastically, depending upon the operating mode. The extremes of this operating experience expressed as infiltration rates are listed in Table 2.

TABLE 2
SUMMARY OF INFILTRATION RATES FOR
OPERATING PHASES SHOWN IN FIGURE 1

Bay #	Net Surface (Sq Ft)	Filter Travel (Ft)	Infiltration Rate (Ft ³ /Ft ² /Day)		Remarks
			Max.	Min.	
1	7200	250	0.50	0.35	Phase I
3	4600	150	1.30	.95	Phase II
"	"	"	.77	.57	Phase IV
4	4100	100	2.30	.80	Phase III

TUCSON WASTEWATER RECLAMATION PROJECT

PILOT FILTER SUMP PRODUCTION



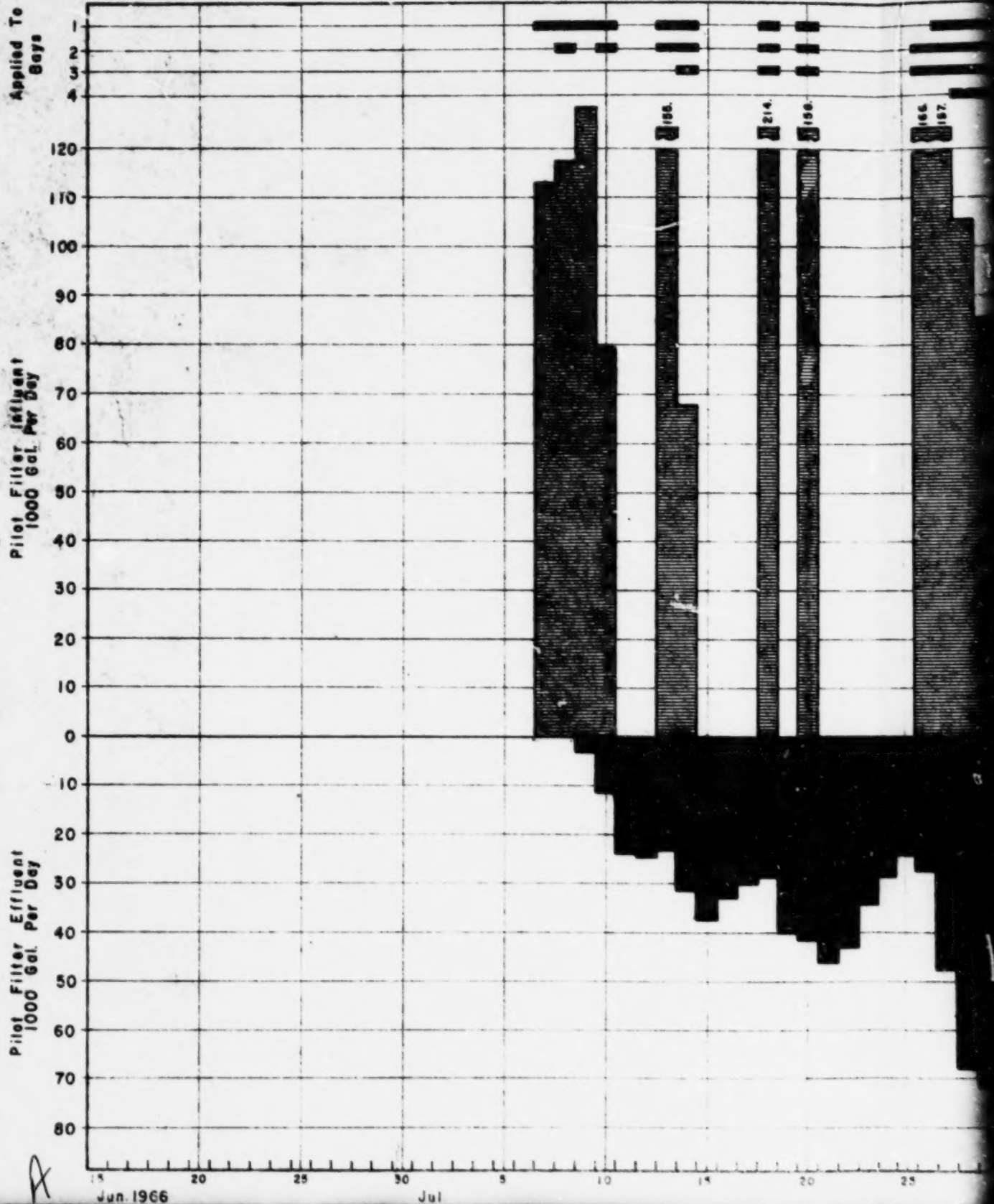
MONTHS OF CONTINUOUS OPERATION

FIG. I

The gravel surfaced filter media in use has permitted passage of a maximum of 2.3 cubic feet per square foot per day with a diminishing free standing head of two feet. Loss of infiltration capability down to 0.80 feet per day with highest available hydraulic gradient from application to recovery points was experienced.

Considerable hydraulic data taken at interval filter points is undergoing rigorous mathematical analysis at this time, and the mechanics of Pilot Filter Hydraulics, as related to filter media permeability, infiltration rate, hydraulic gradient and standing water head as supplemented by Dye study and other analytical data, will be reported in forthcoming transmittals.

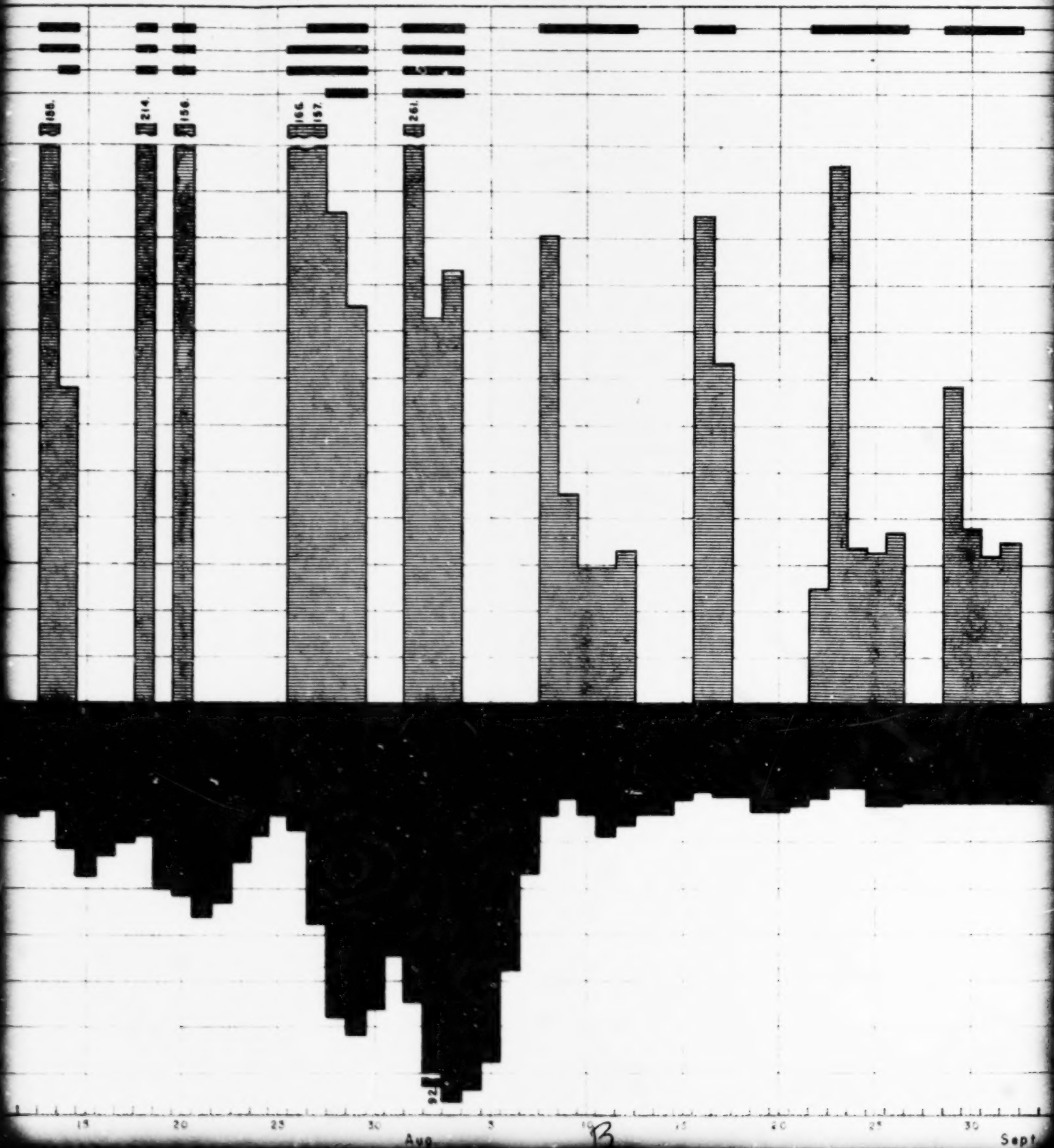
TUCSON WASTEWATER Pilot Filter Operati



UCSON WASTEWATER RECLAMATION PROJECT

Pilot Filter Operation and Performance

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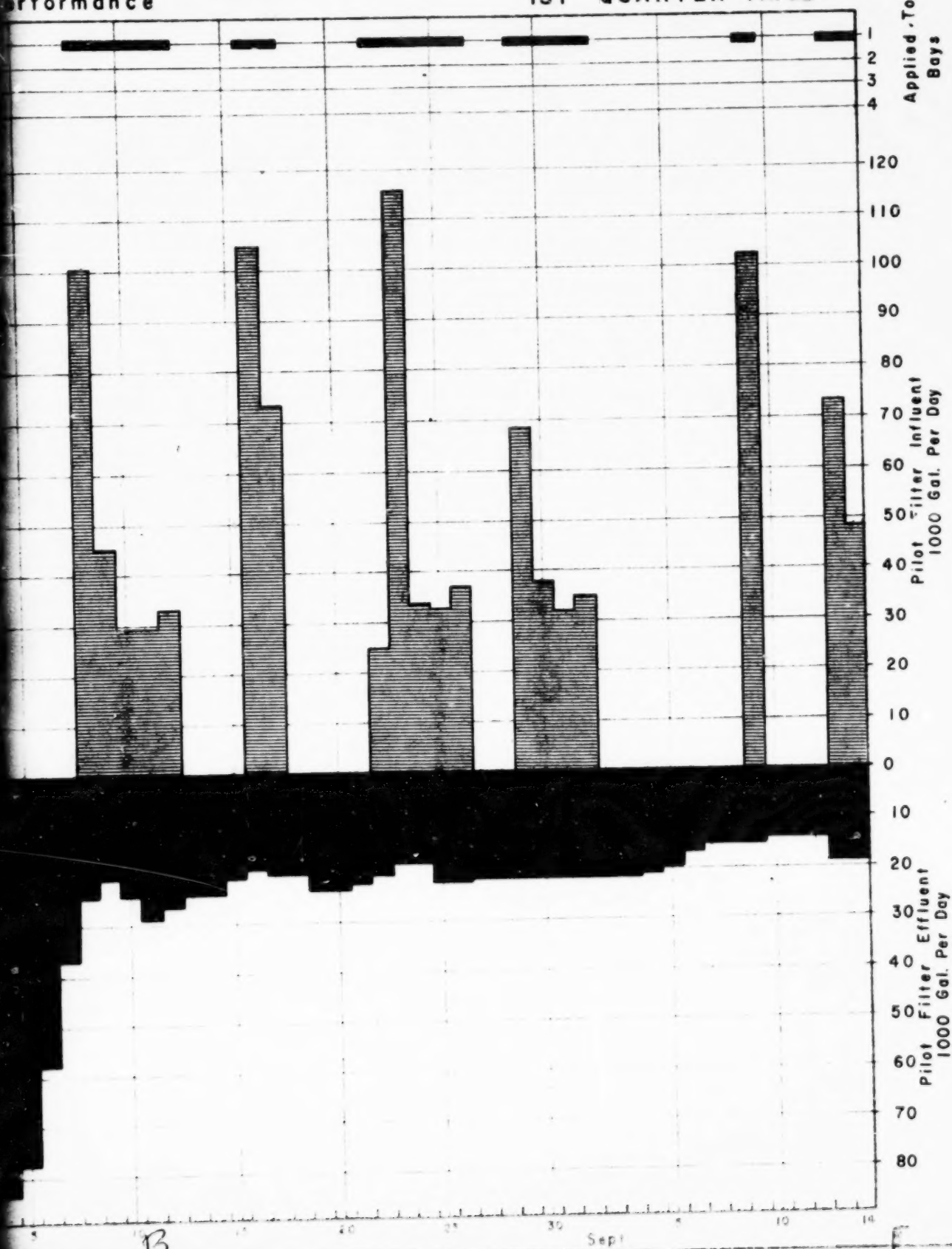


LAMINATION PROJECT

Performance

PLATE 1

1ST QUARTER-YR.02

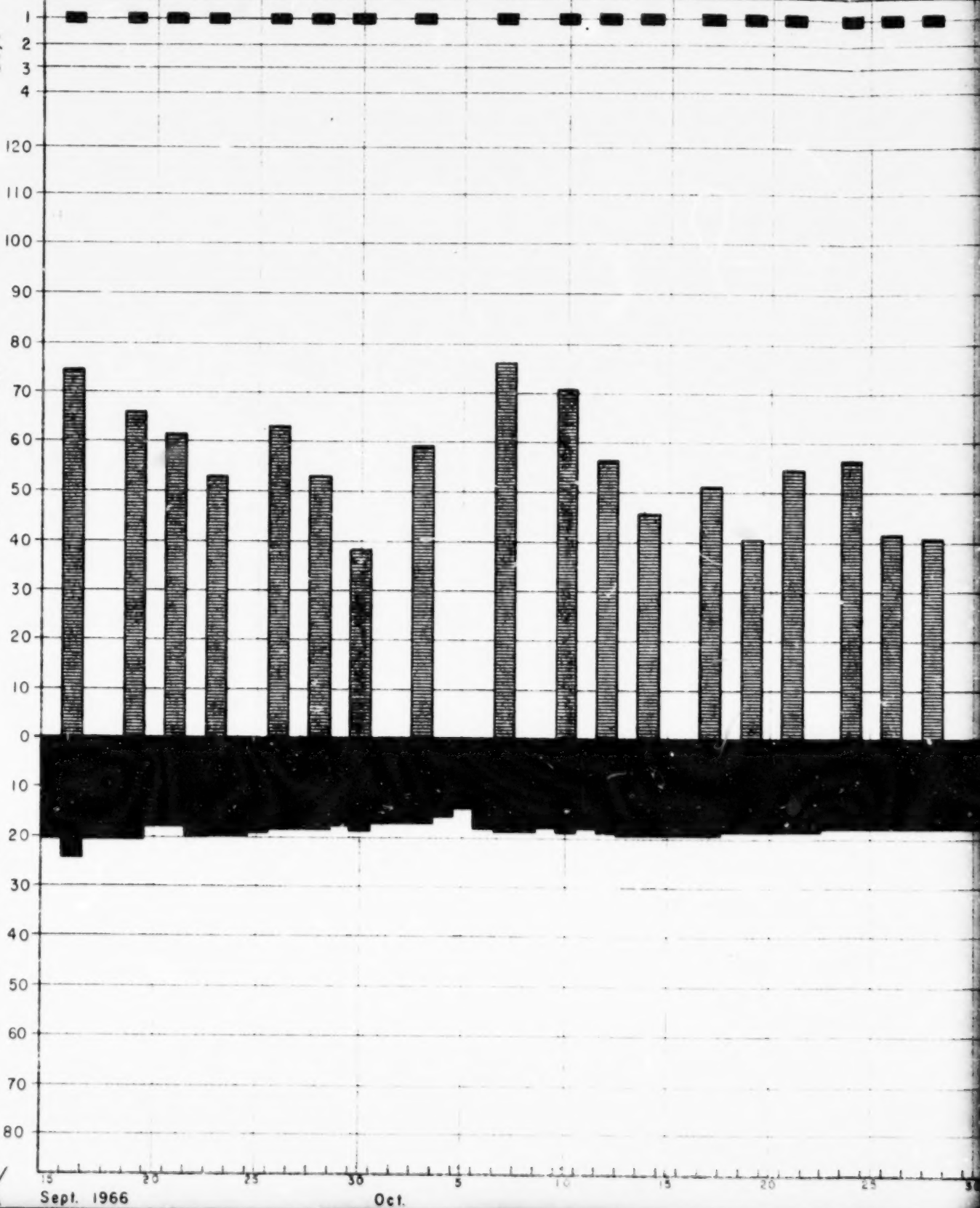


TUCSON WASTEWATER Pilot Filter Operation

Applied To
Boys

Pilot Filter Effluent
1000 Gal. Per Day

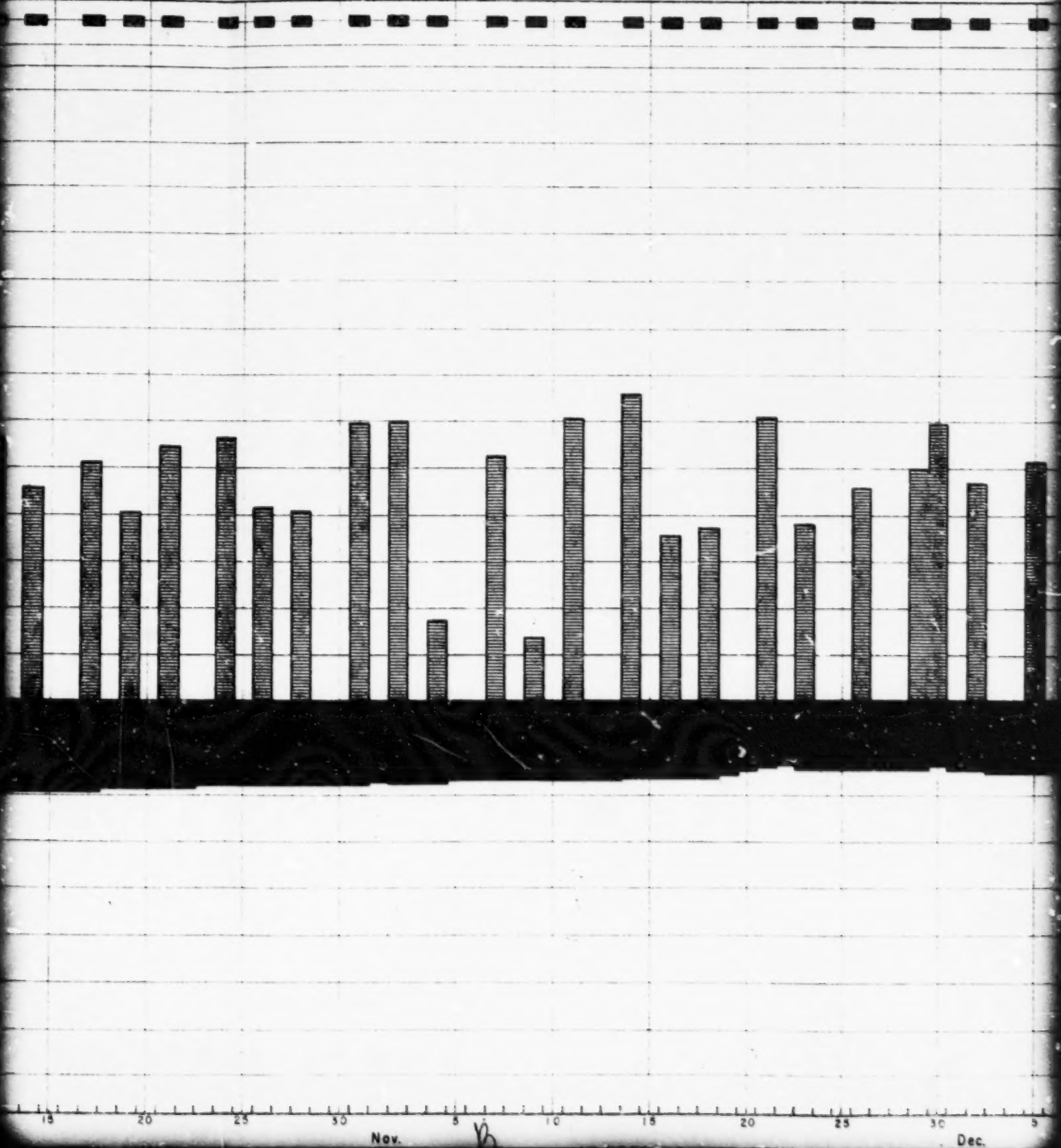
Pilot Filter Effluent
1000 Gal. Per Day



SON WASTEWATER RECLAMATION PROJECT

Pilot Filter Operation and Performance

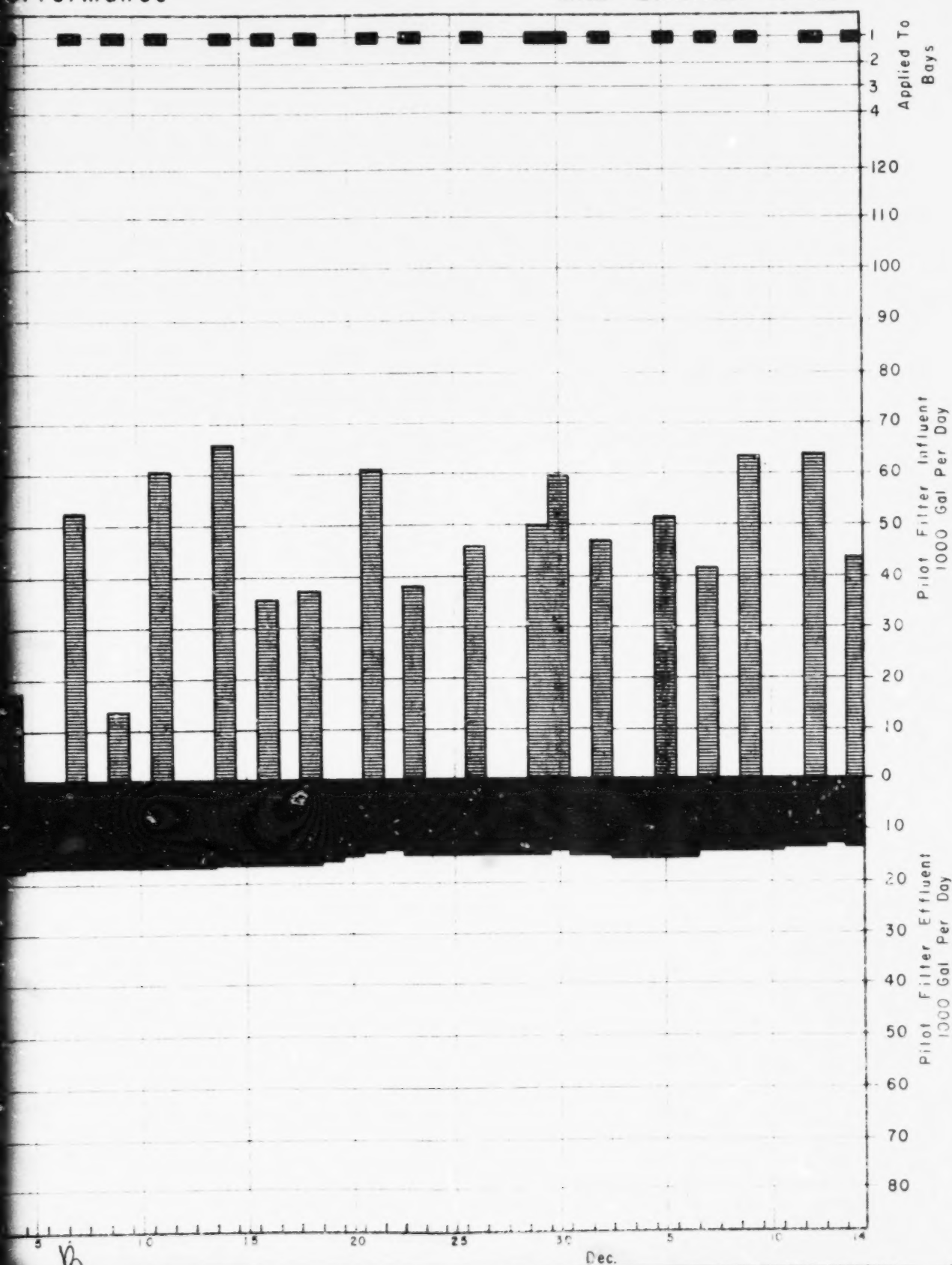
2ND QUA



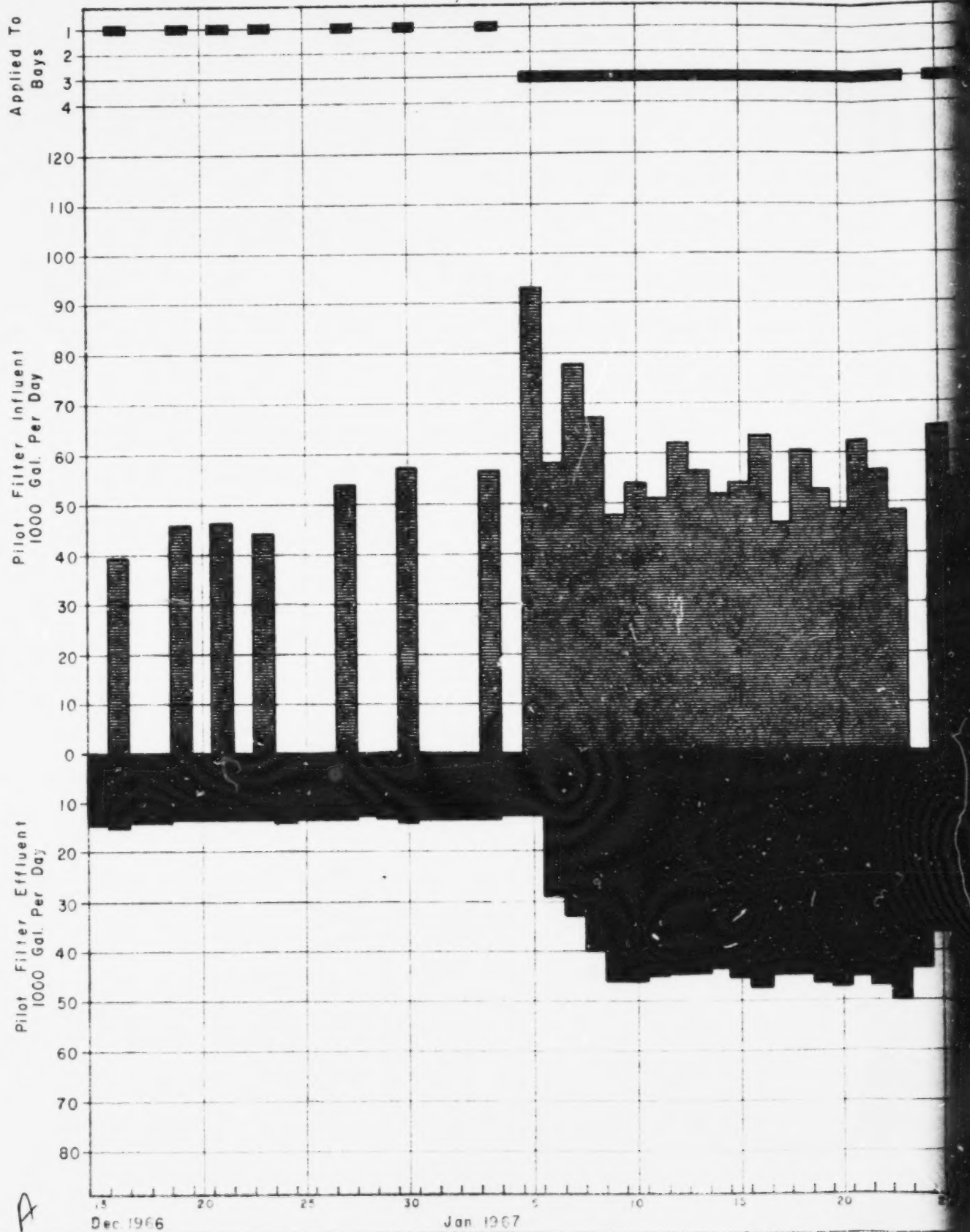
AMATION PROJECT Performance

PLATE 2

2ND QUARTER - YR. 02



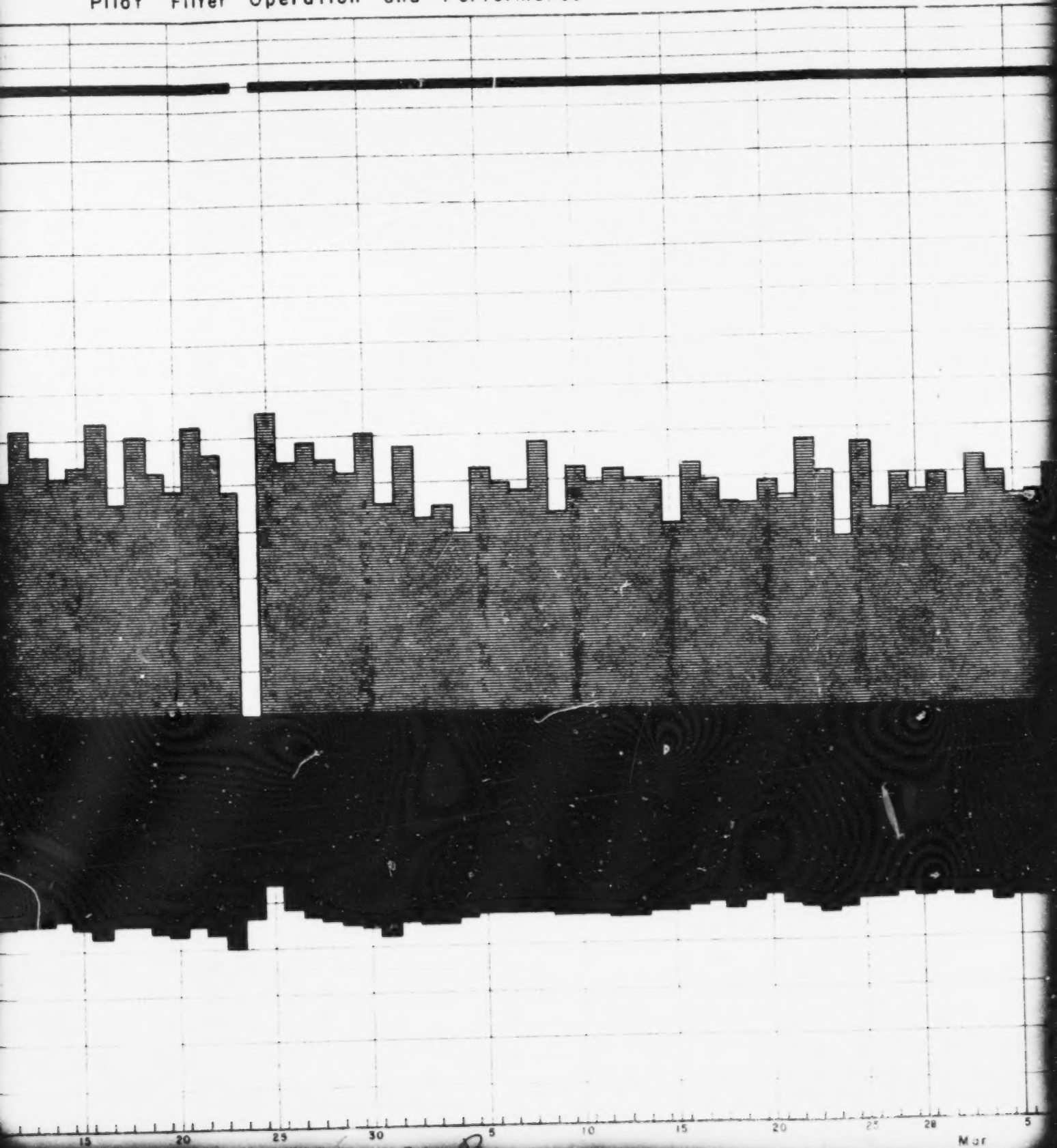
TUCSON WASTEWATER Pilot Filter Op



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ON WASTEWATER RECLAMATION PROJECT
Pilot Filter Operation and Performance

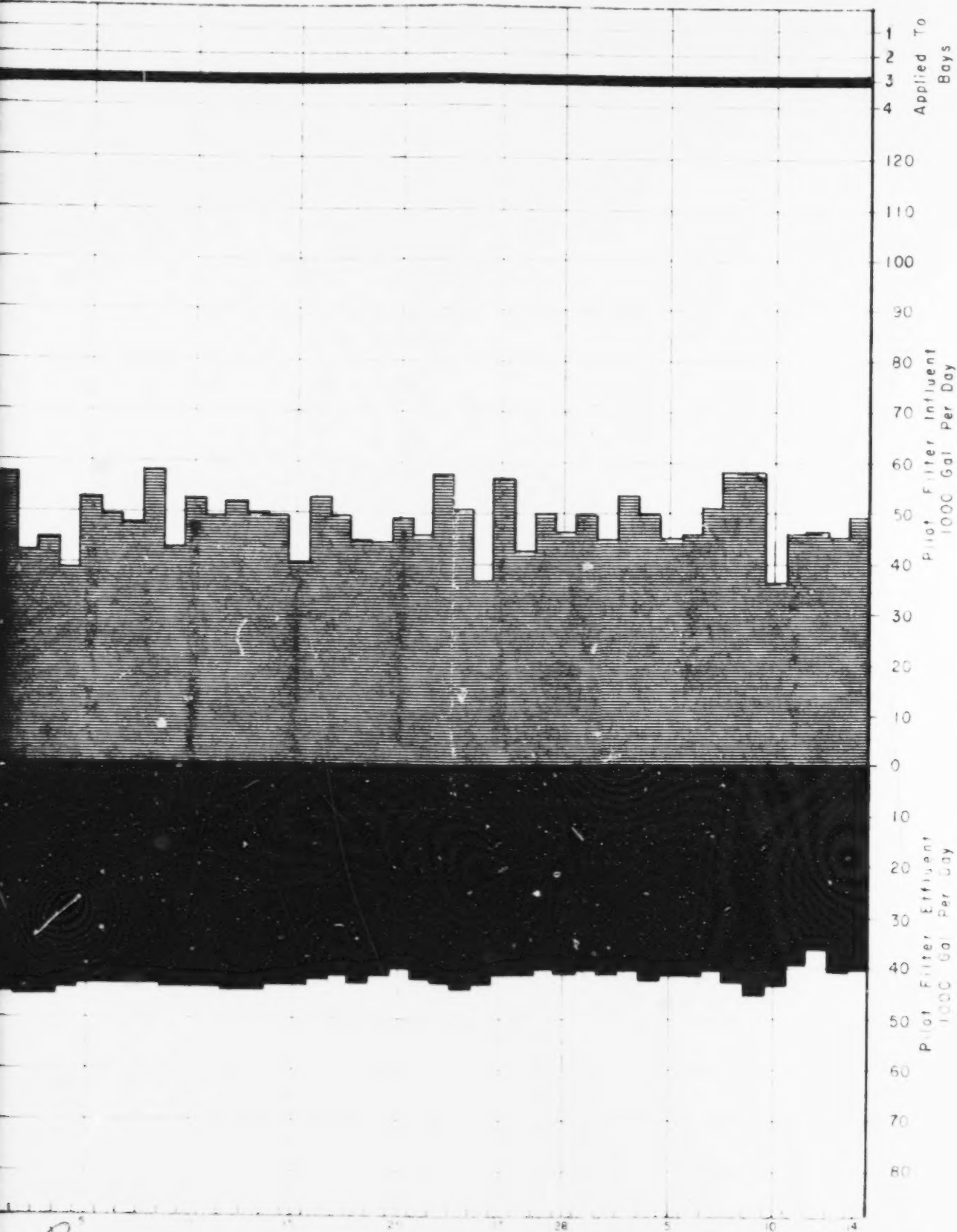
3 RD QUARTER



LAMINATION PROJECT and Performance

PLATE 3

3RD QUARTER - YR. 02



TUCSON WASTEWATER

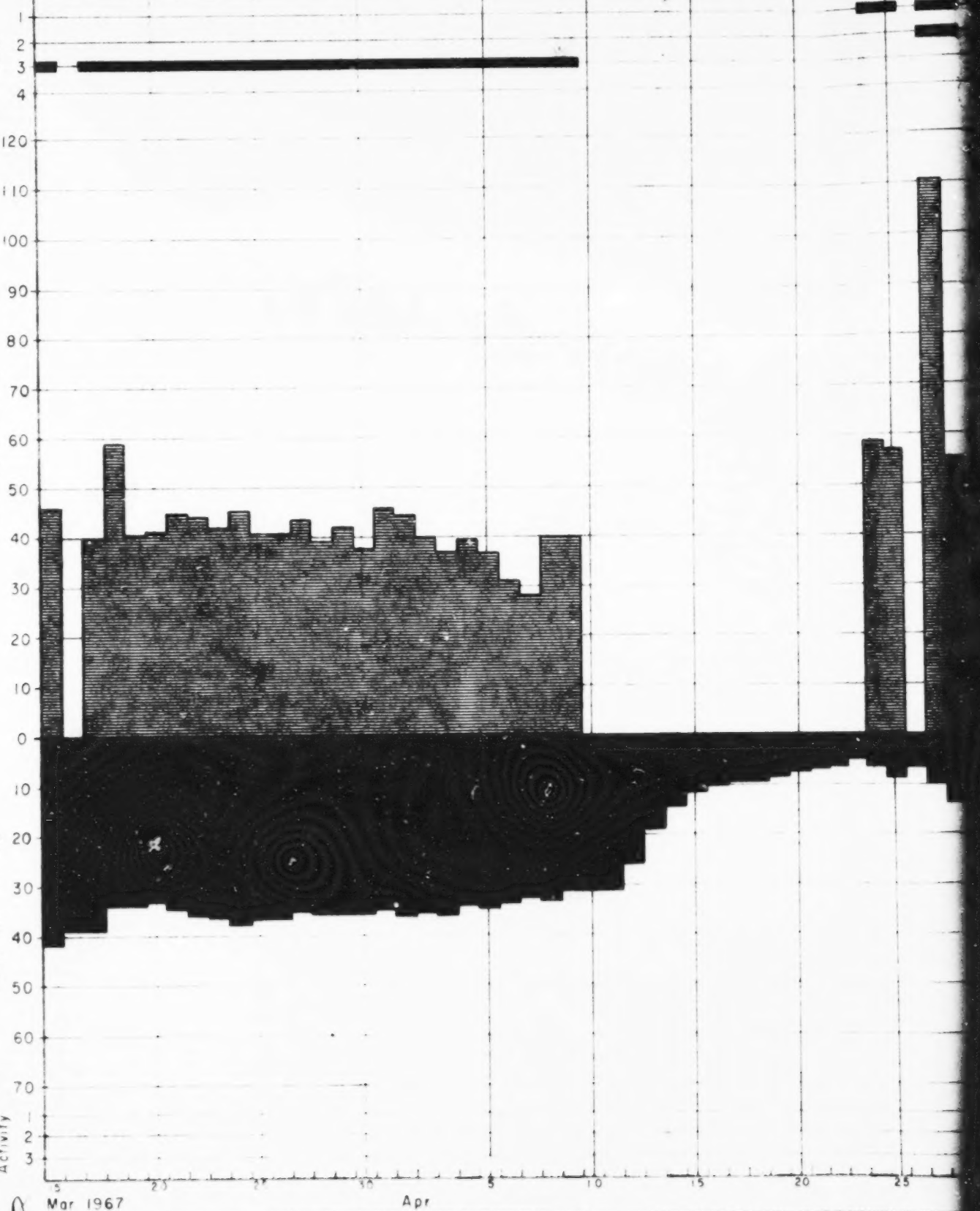
Pilot Filter Operation

Applied To
Bays

Pilot Filter Influent
1000 Gal Per Day

Pilot Filter Effluent
1000 Gal Per Day

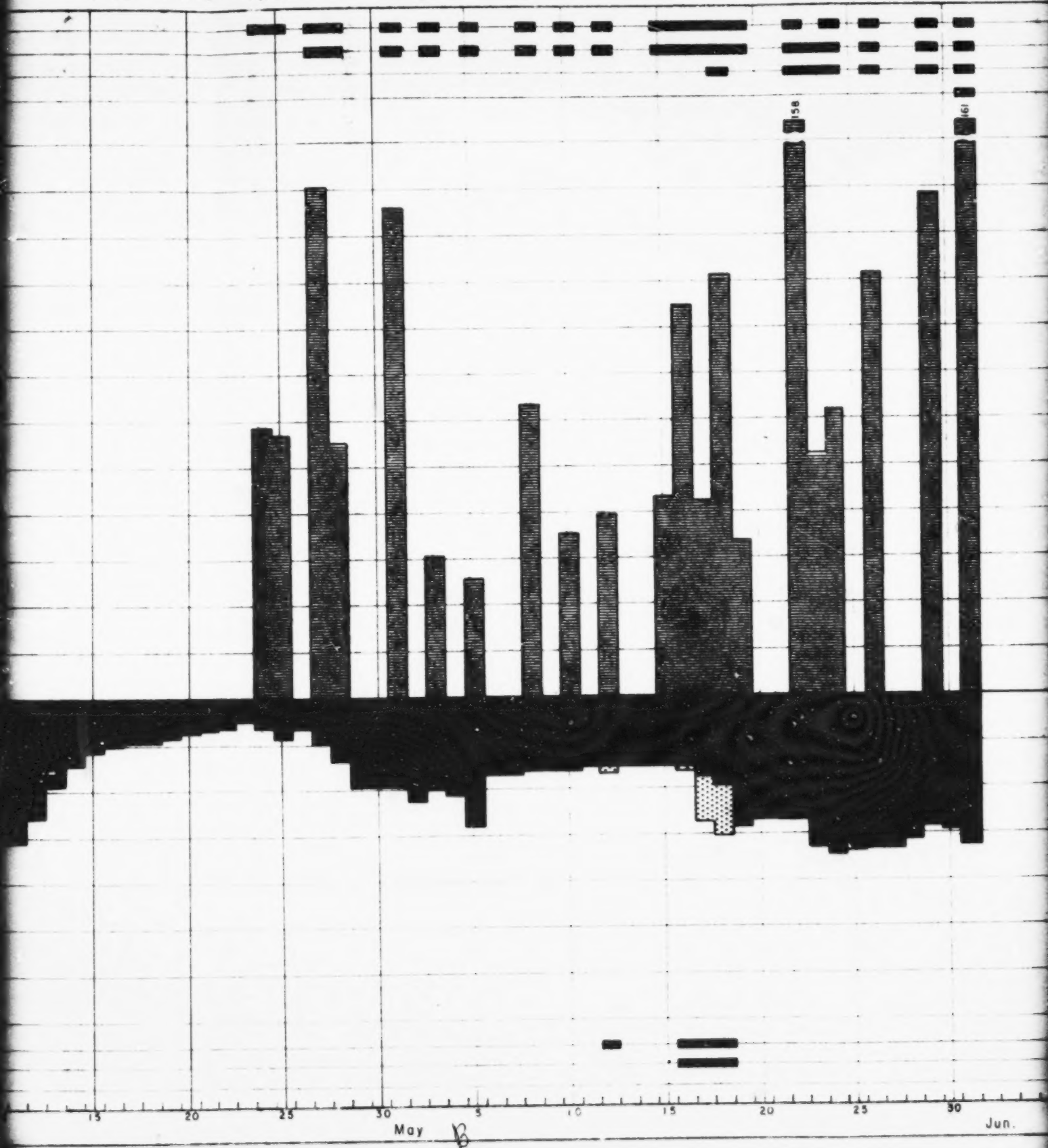
CMP
Pumping
Activity



SON WASTEWATER RECLAMATION PROJECT

Pilot Filter Operation and Performance

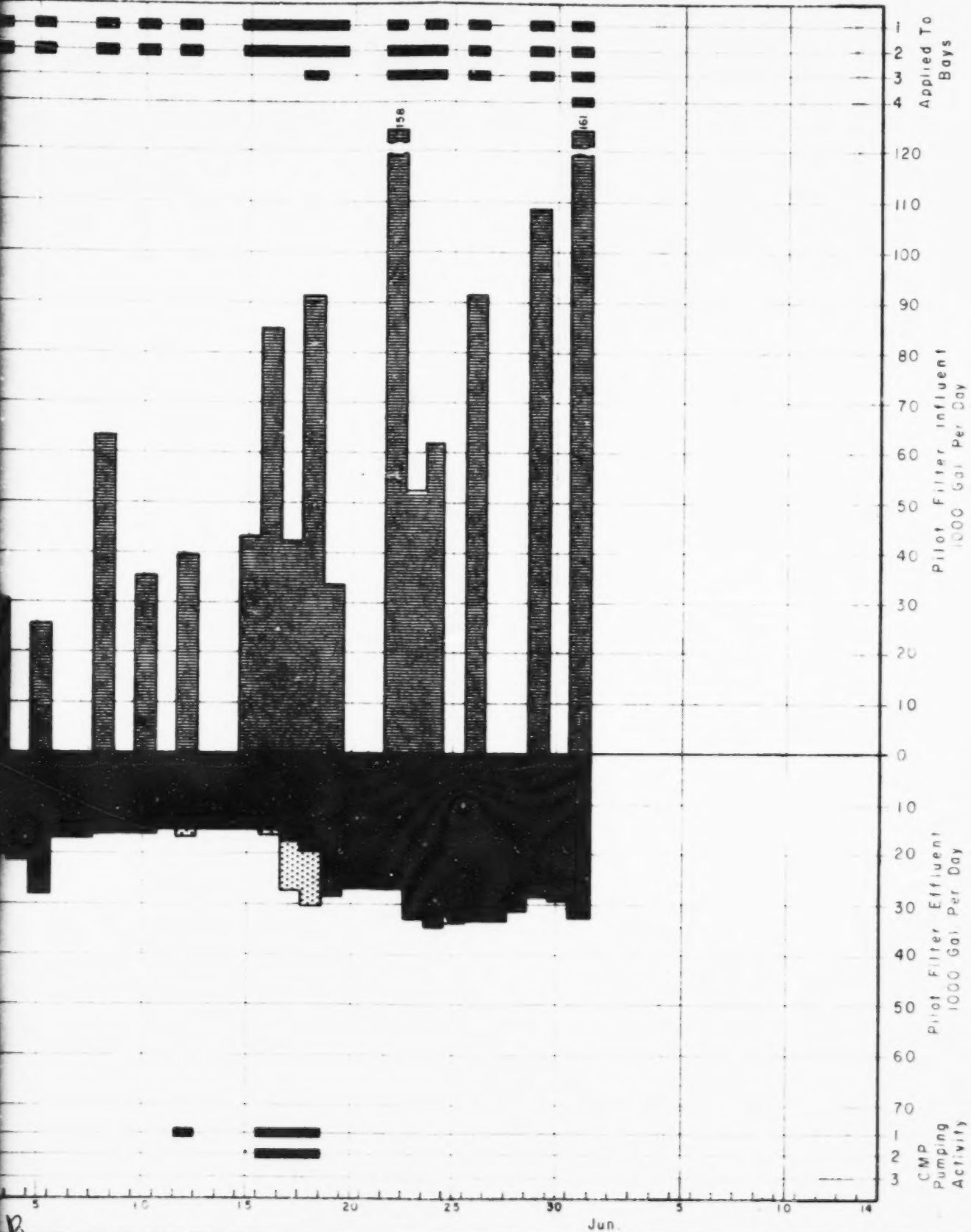
4TH QUA



LAMATION PROJECT
Performance

PLATE 4

4TH QUARTER - YR. 02



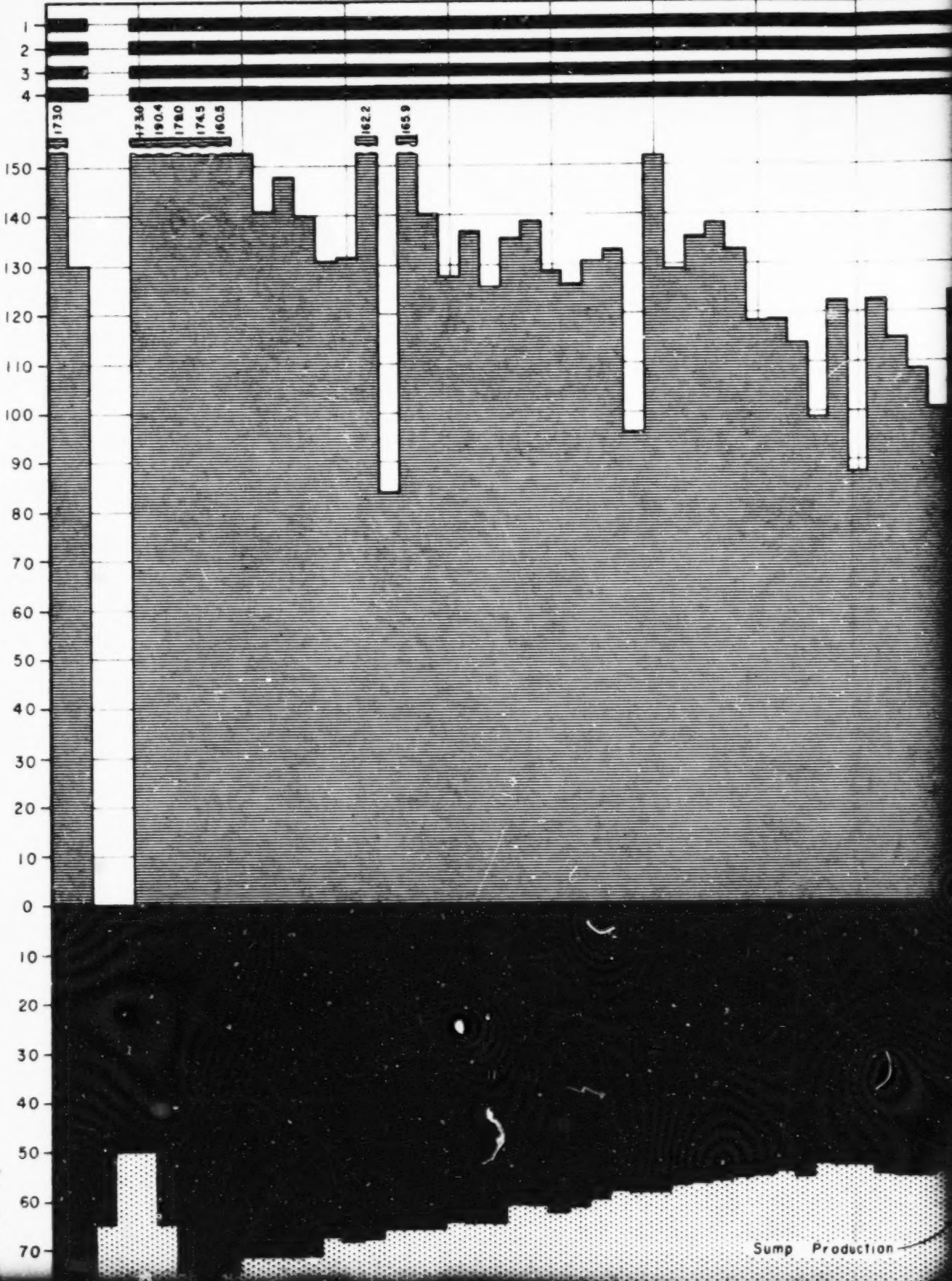
TUCSON WAST

Pilot Fil

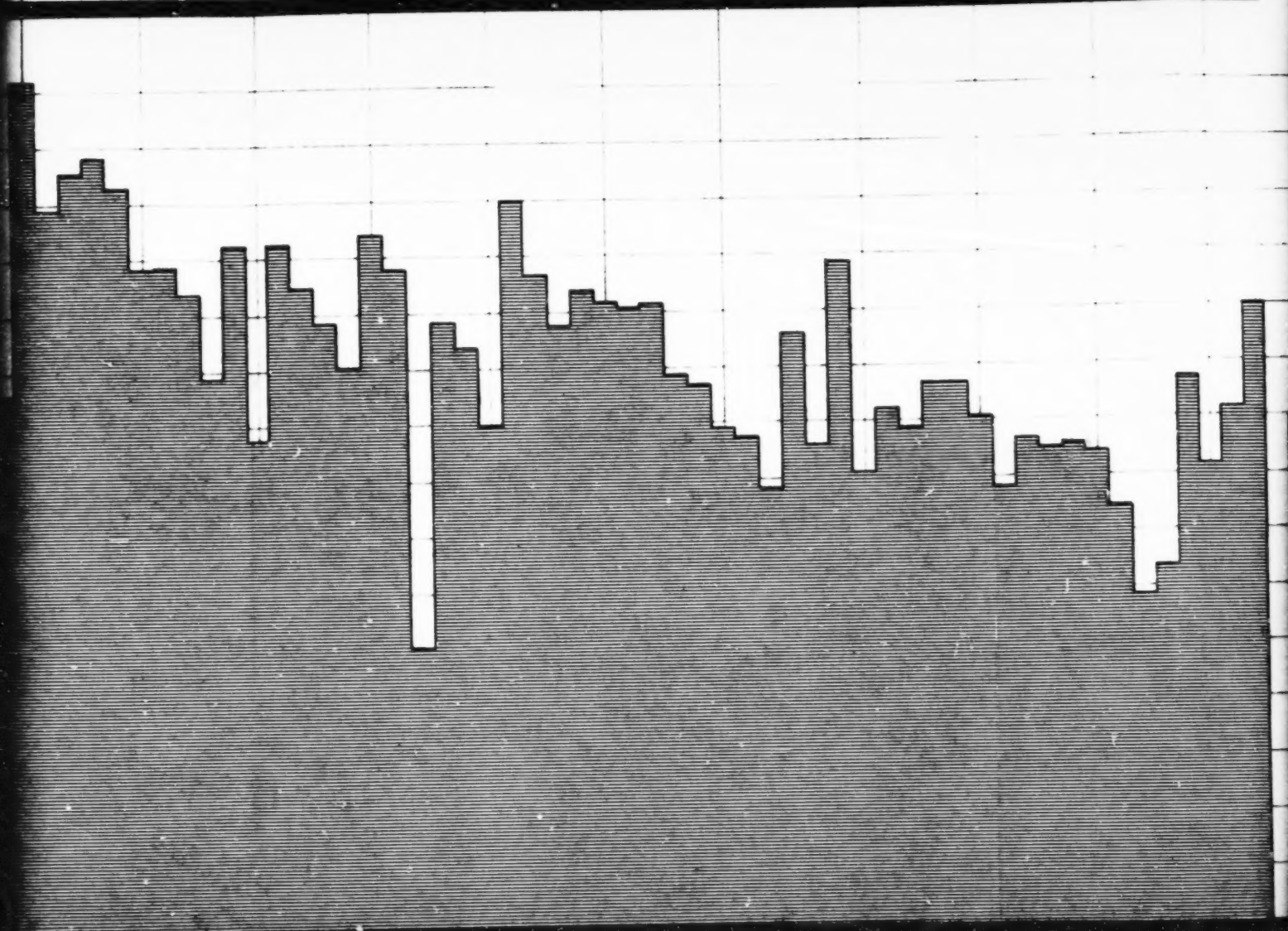
Applied To
Bays

Pilot Filter Influent
1000 Gal Per Day

Effluent
Gal Per Day

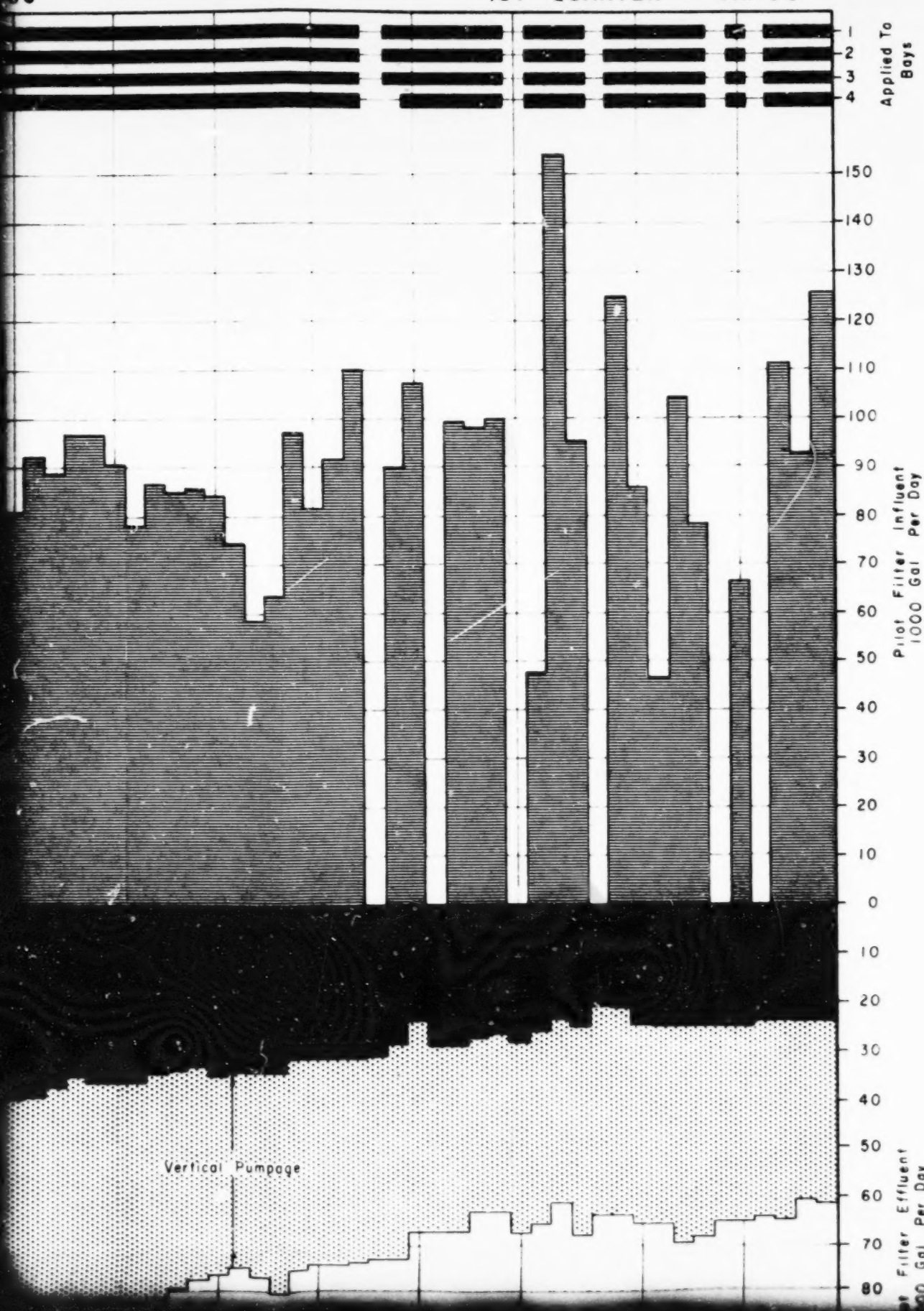


¹³
TUCSON WASTEWATER RECLAMATION PROJECT
Pilot Filter Operation and Performance



Sump Production

Vertical Pumpage



Pilot Filter Influent
1000 Gal Per Day

100
90
80
70
60
50
40
30
20
10
0

Pilot Filter Effluent
1000 Gal Per Day

10
20
30
40
50
60
70
80
90
100
110
120
130
140
150

CMP
Pumping
Activity

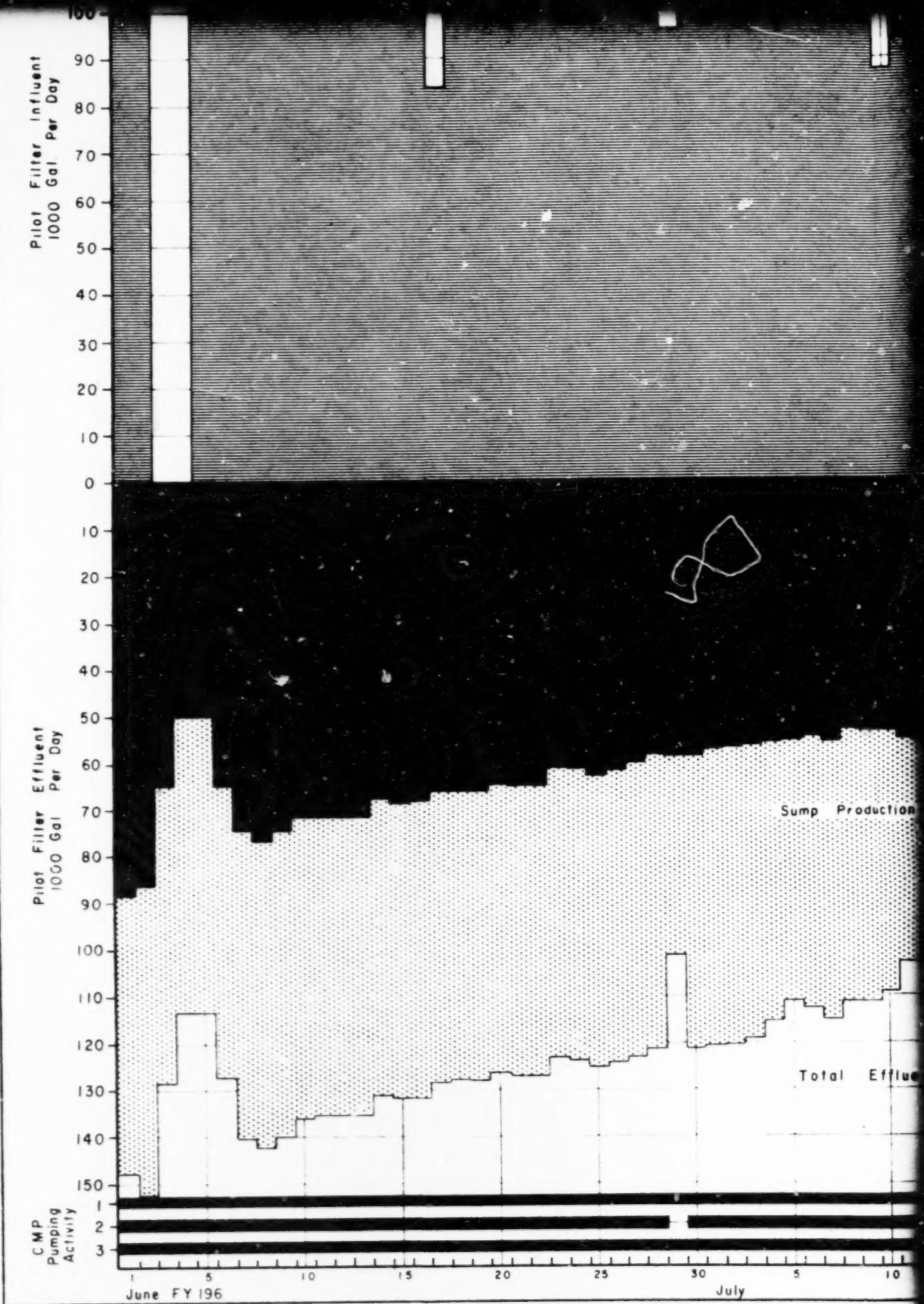
1
2
3

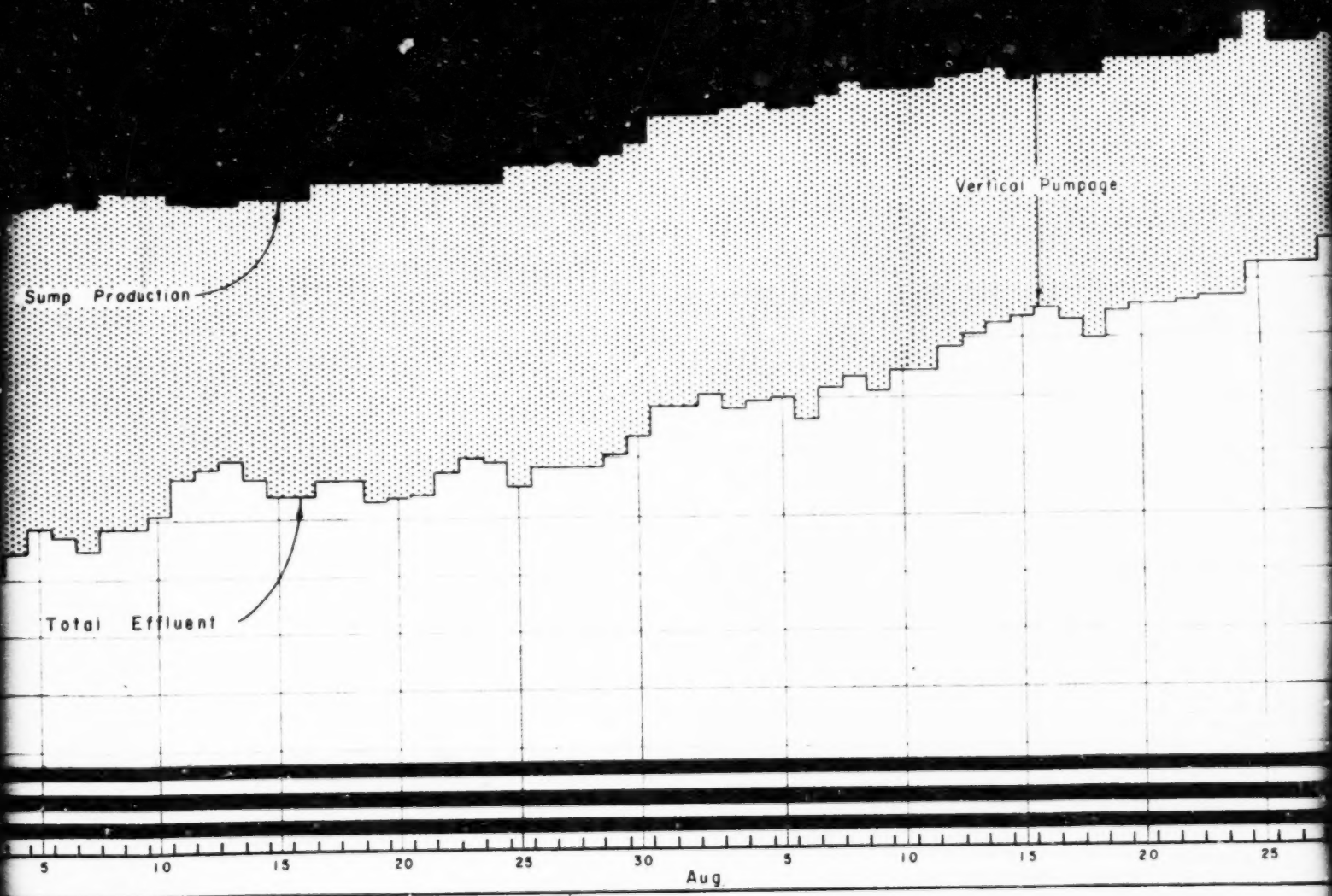
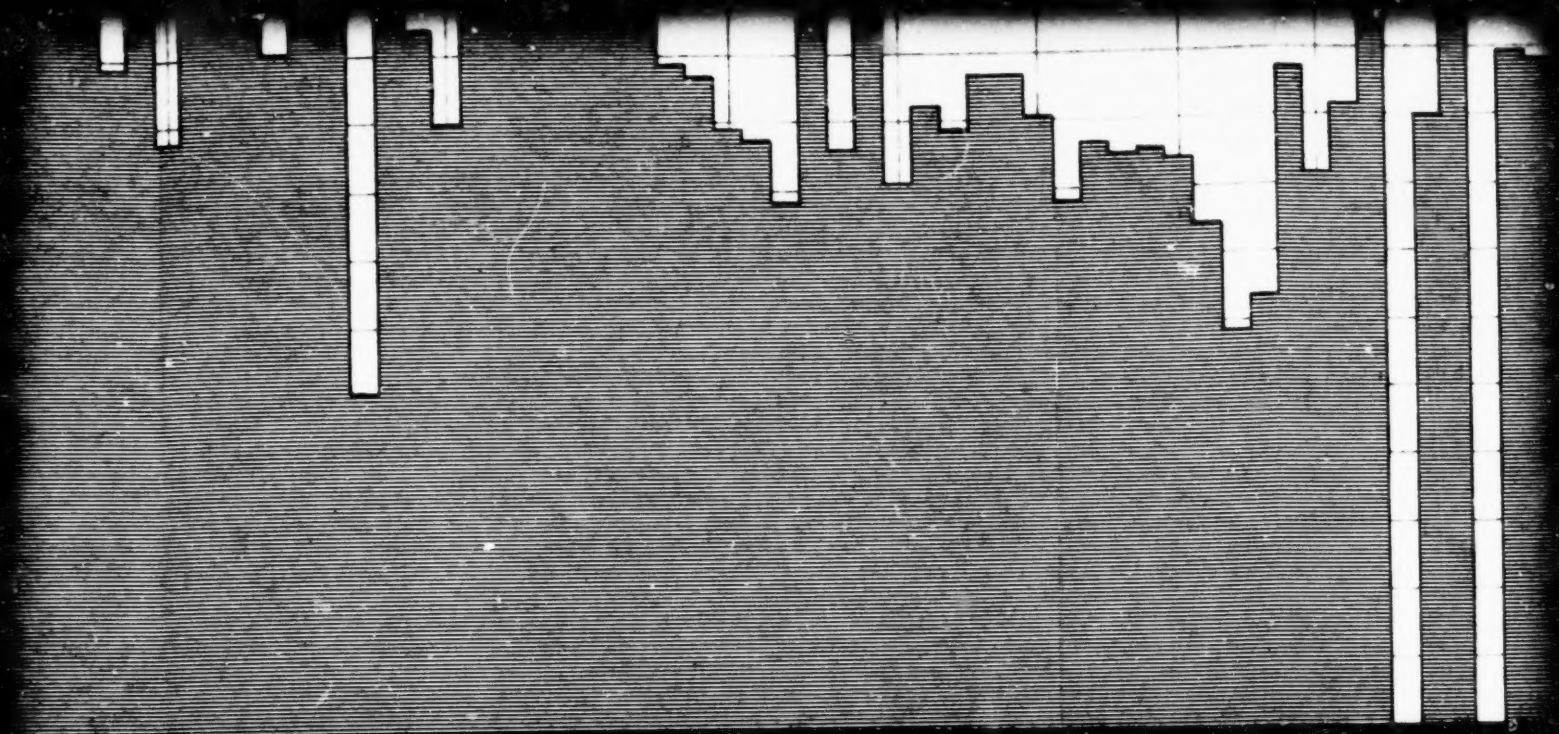
June FY 196

July

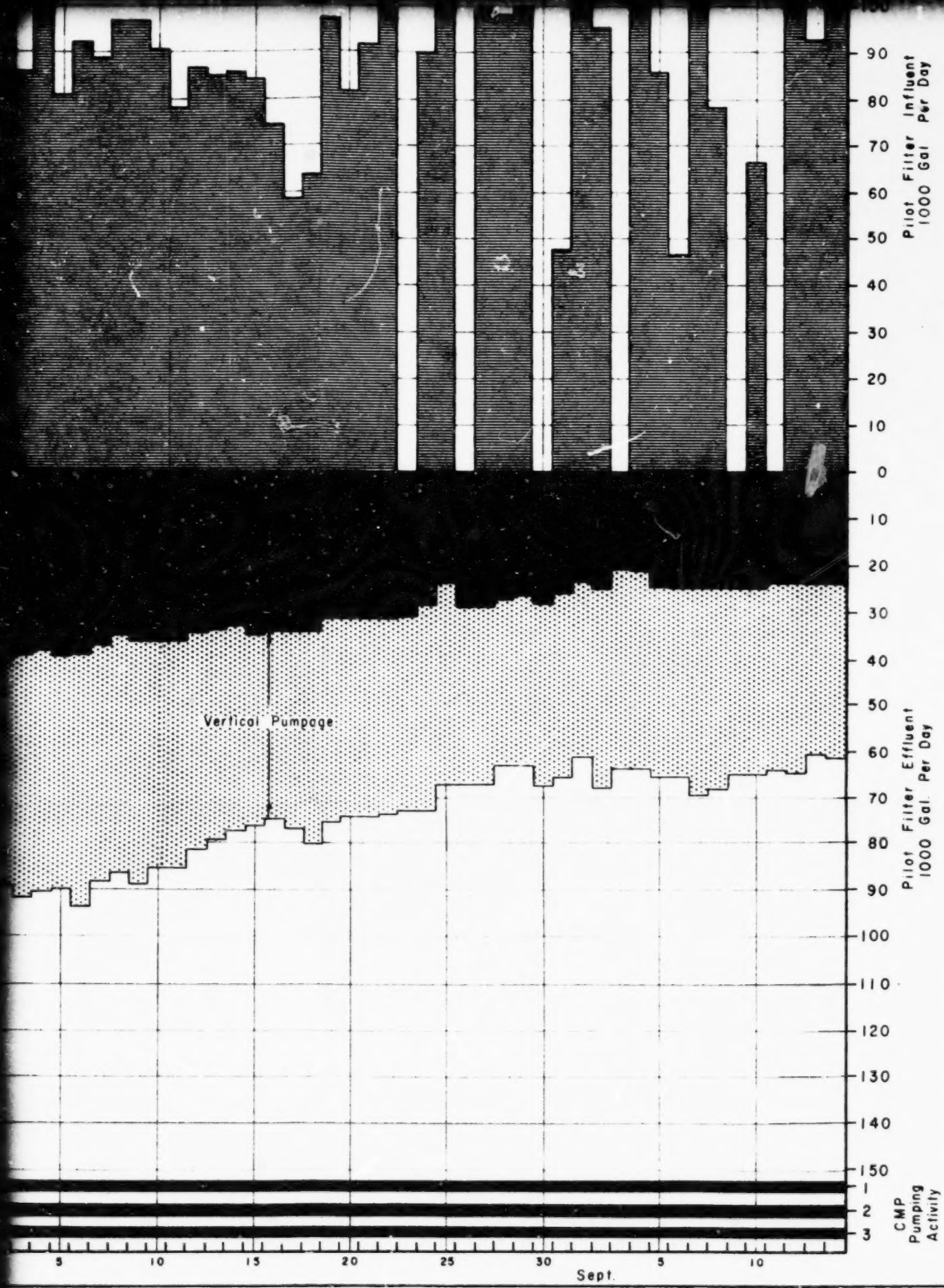
Sump Production

Total Effluent



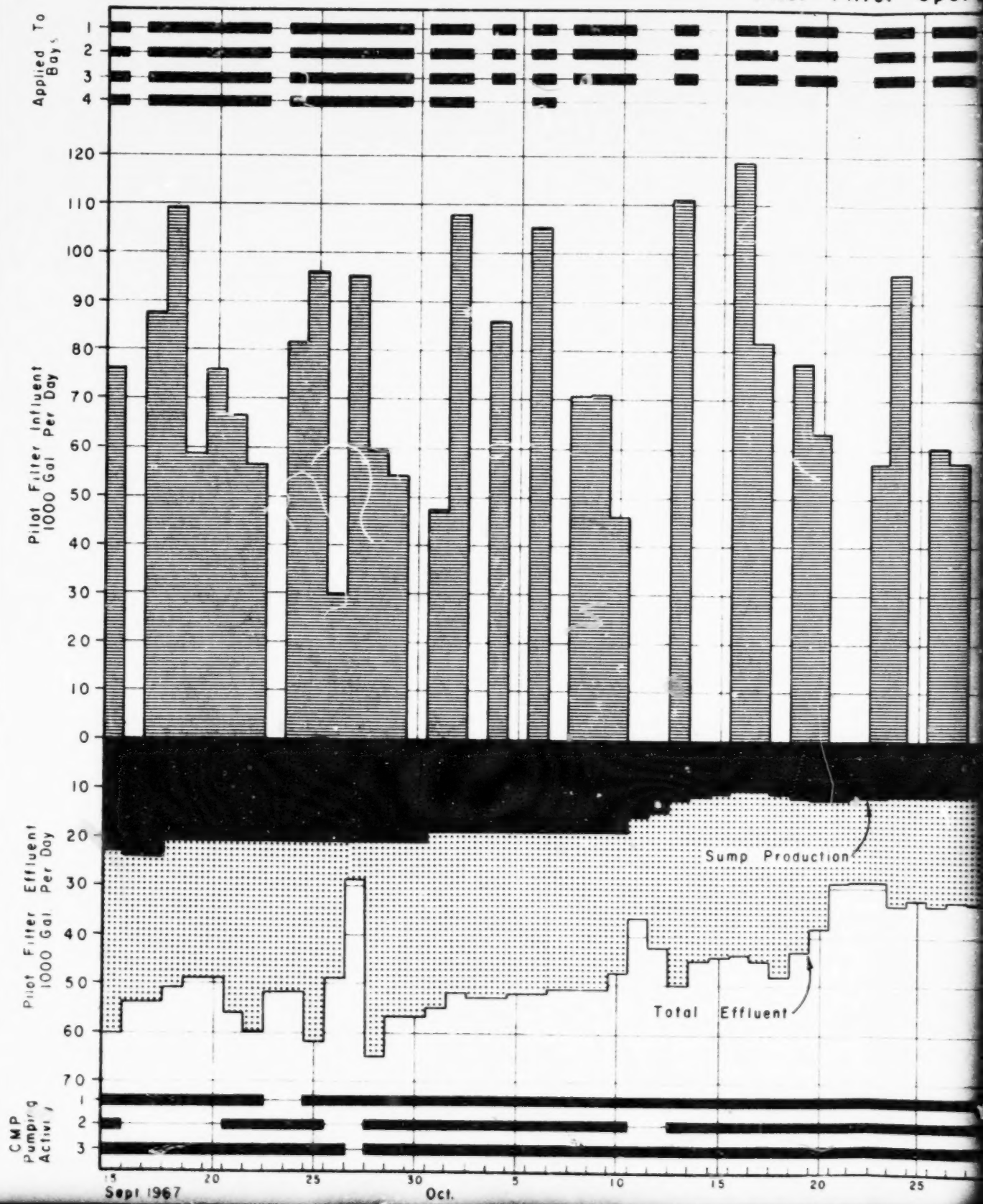


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F

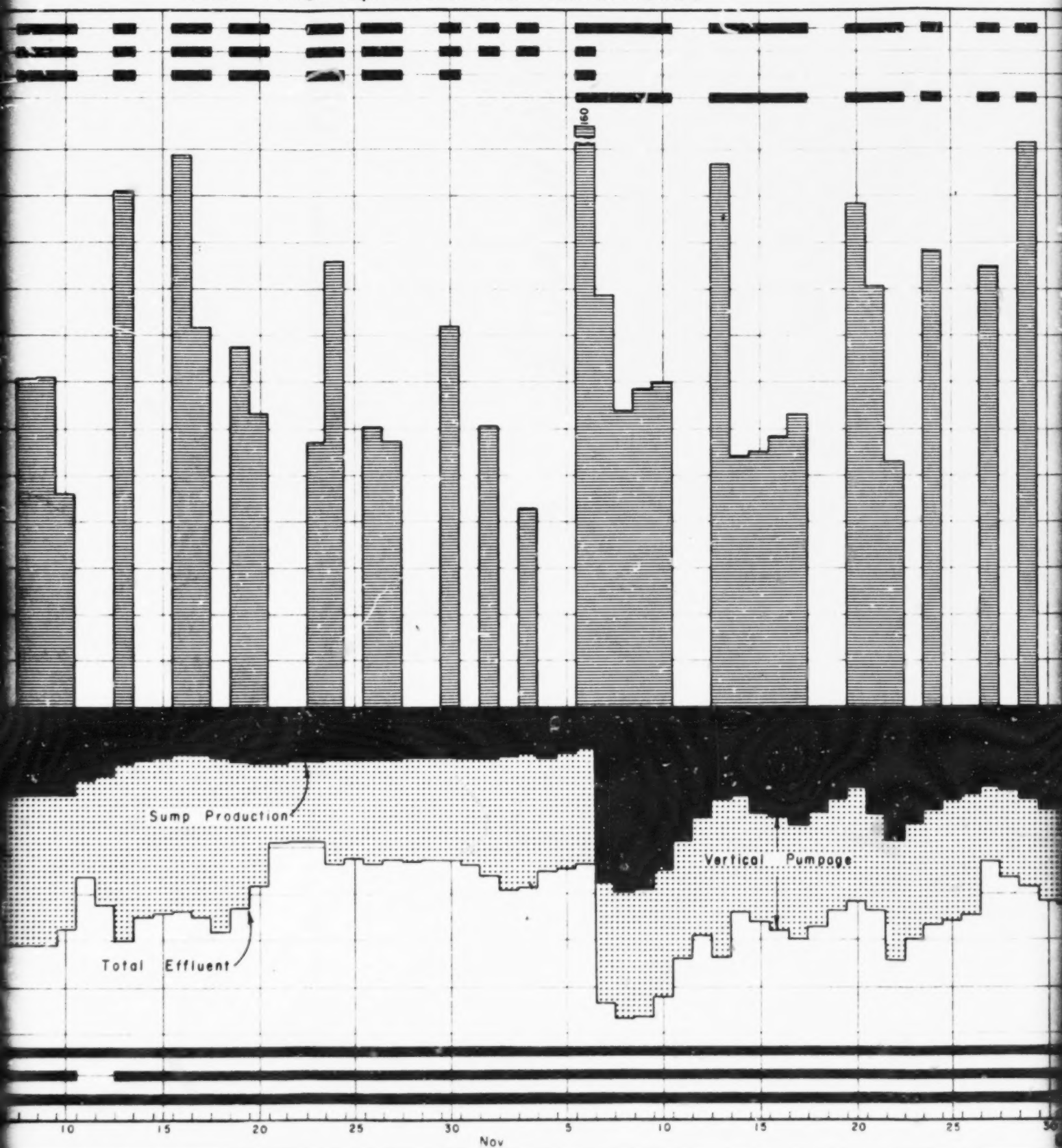
TUCSON WASTEWATER Pilot Filter Oper



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TUCSON WASTEWATER RECLAMATION PROJECT

Pilot Filter Operation and Performance



B

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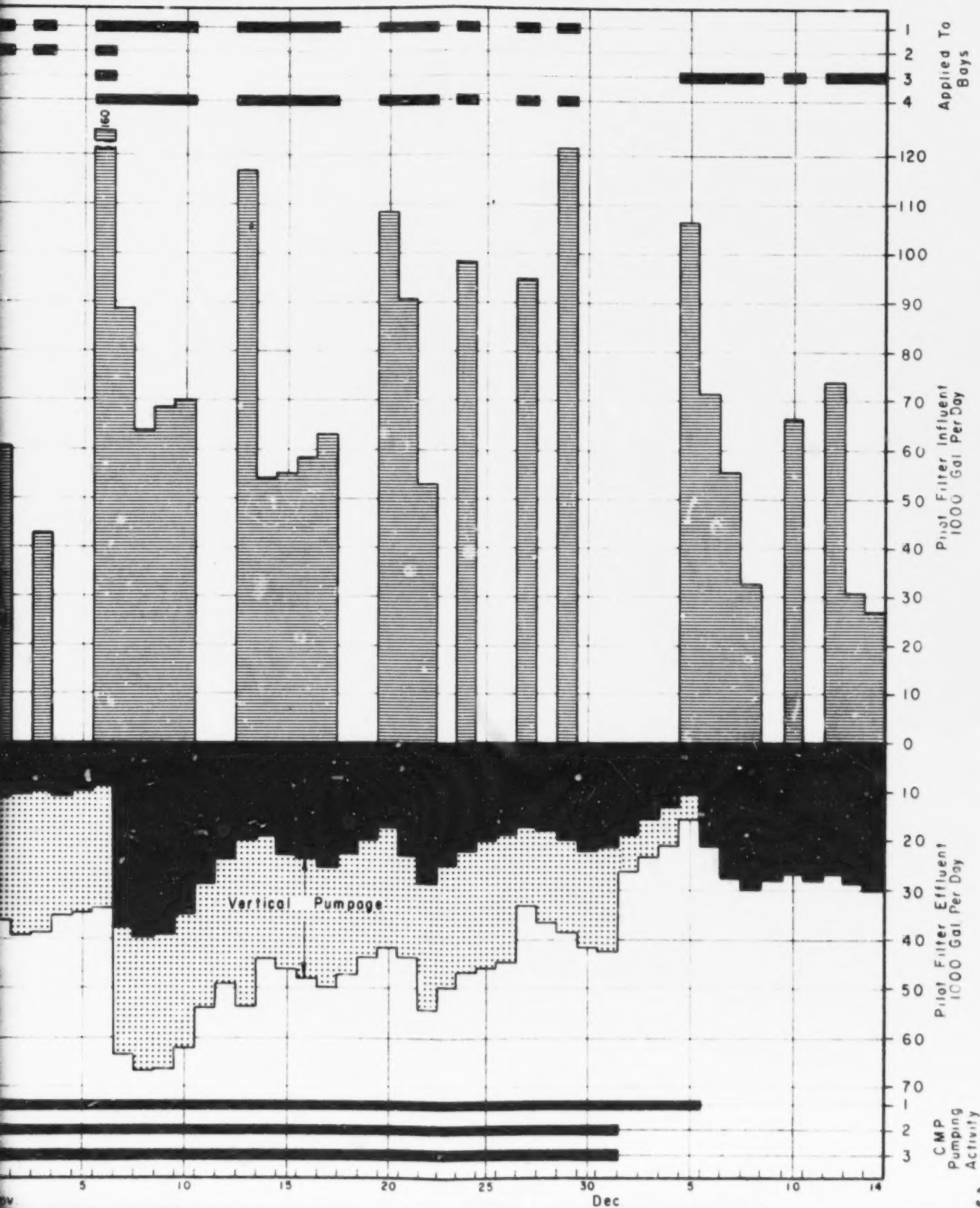
DECLAMATION PROJECT

and Performance

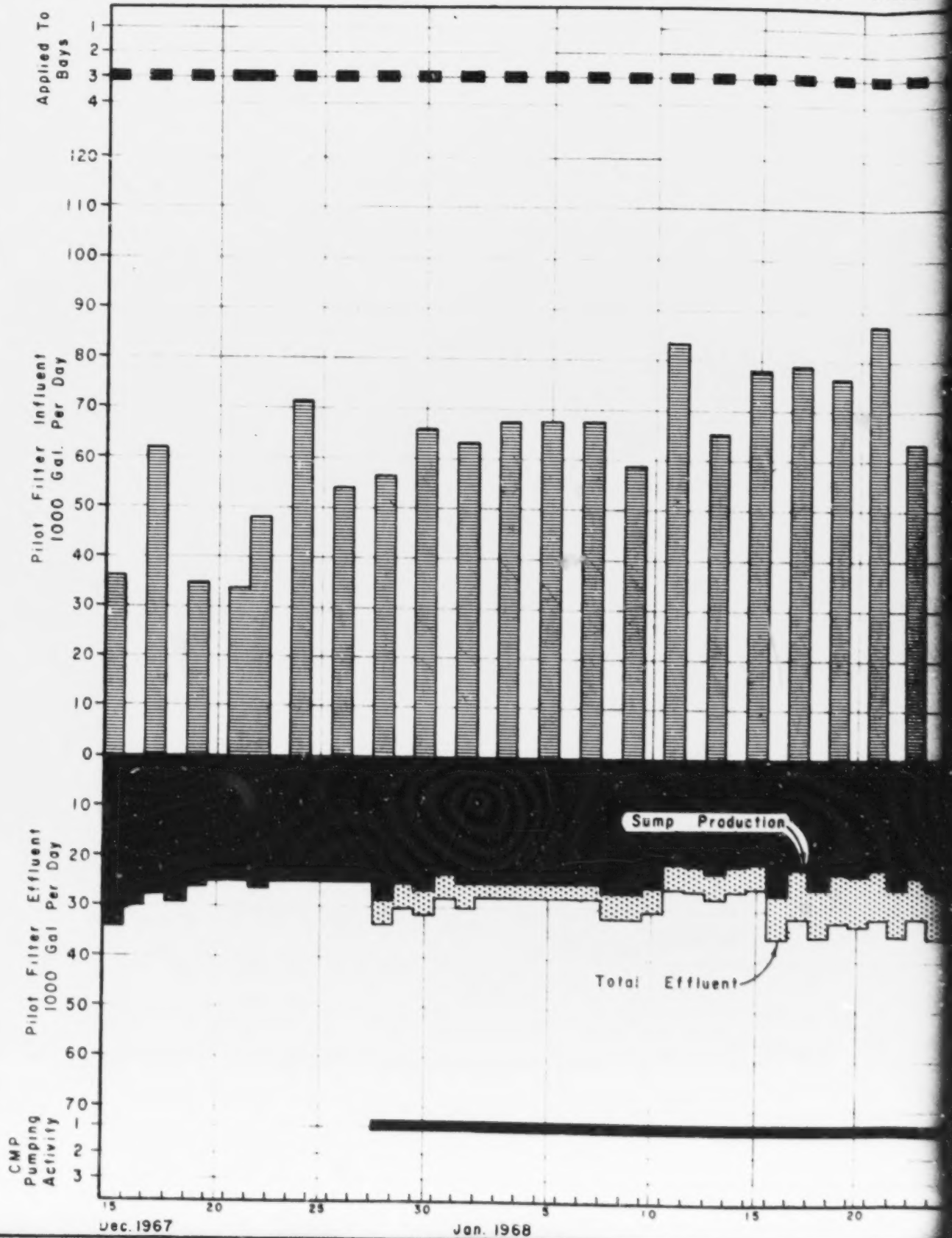
PLATE 6

2ND QUARTER

YR. 03



TUCSON WASTEWATER Pilot Filter

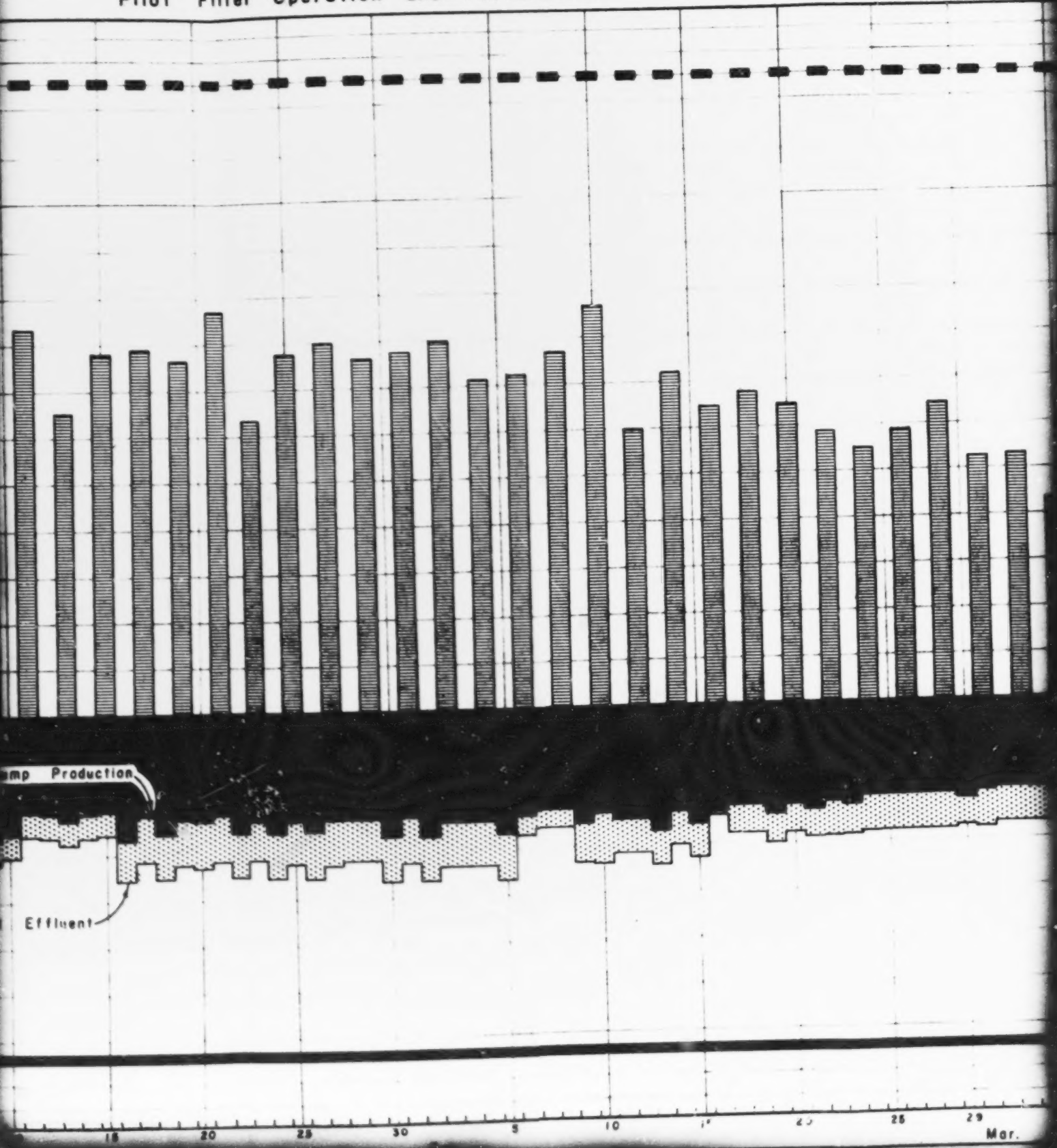


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SON WASTEWATER RECLAMATION PROJECT

Pilot Filter Operation and Performance

3RD QUART



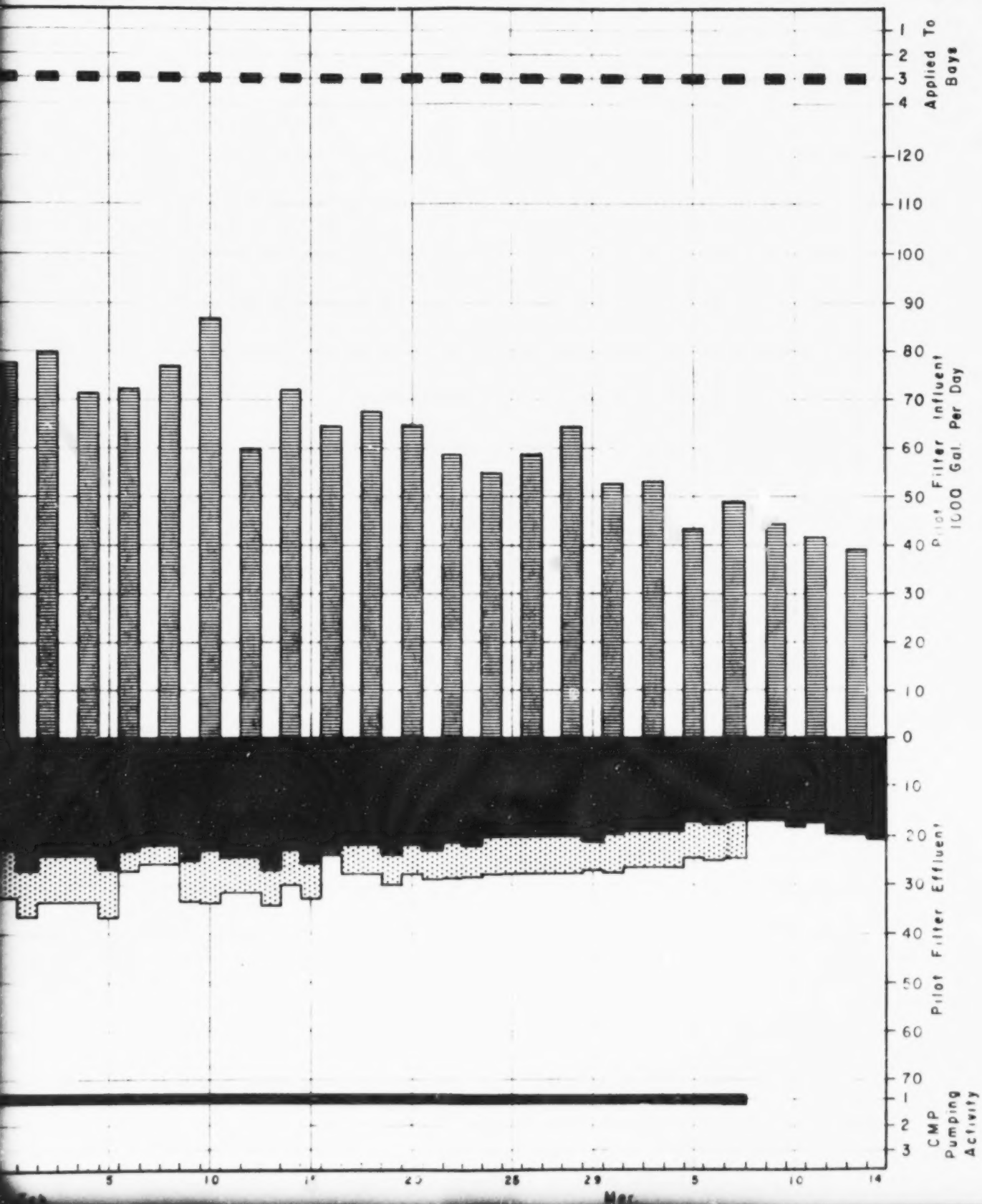
8

CLAMATION PROJECT and Performance

3RD QUARTER

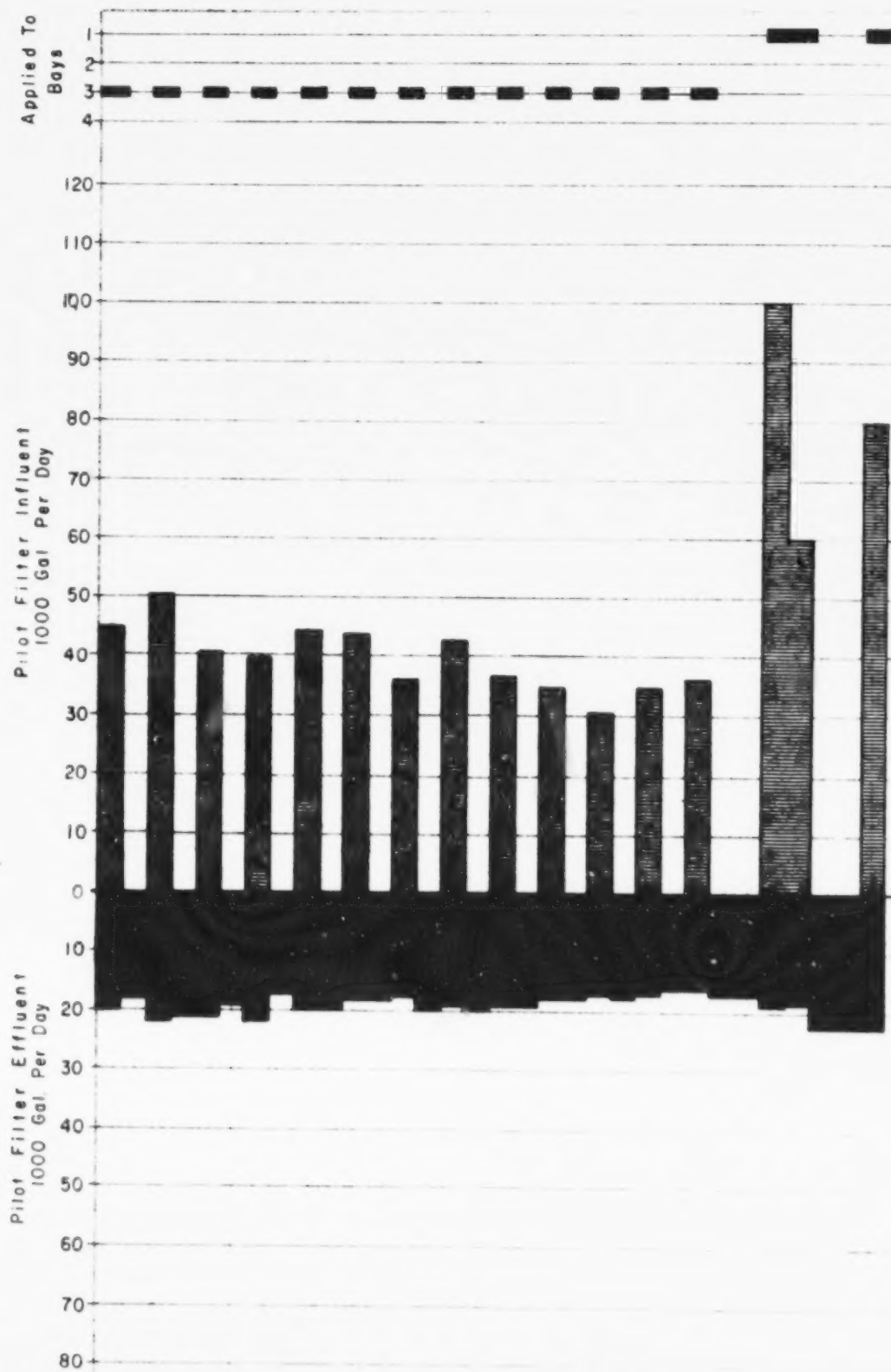
YR. 03

PLATE 7



A

WASTEWATER Plant Report - 1968



B

TUCSON WASTEWATER RECLAMATION PROJECT

Pilot Filter Operation and Performance

4

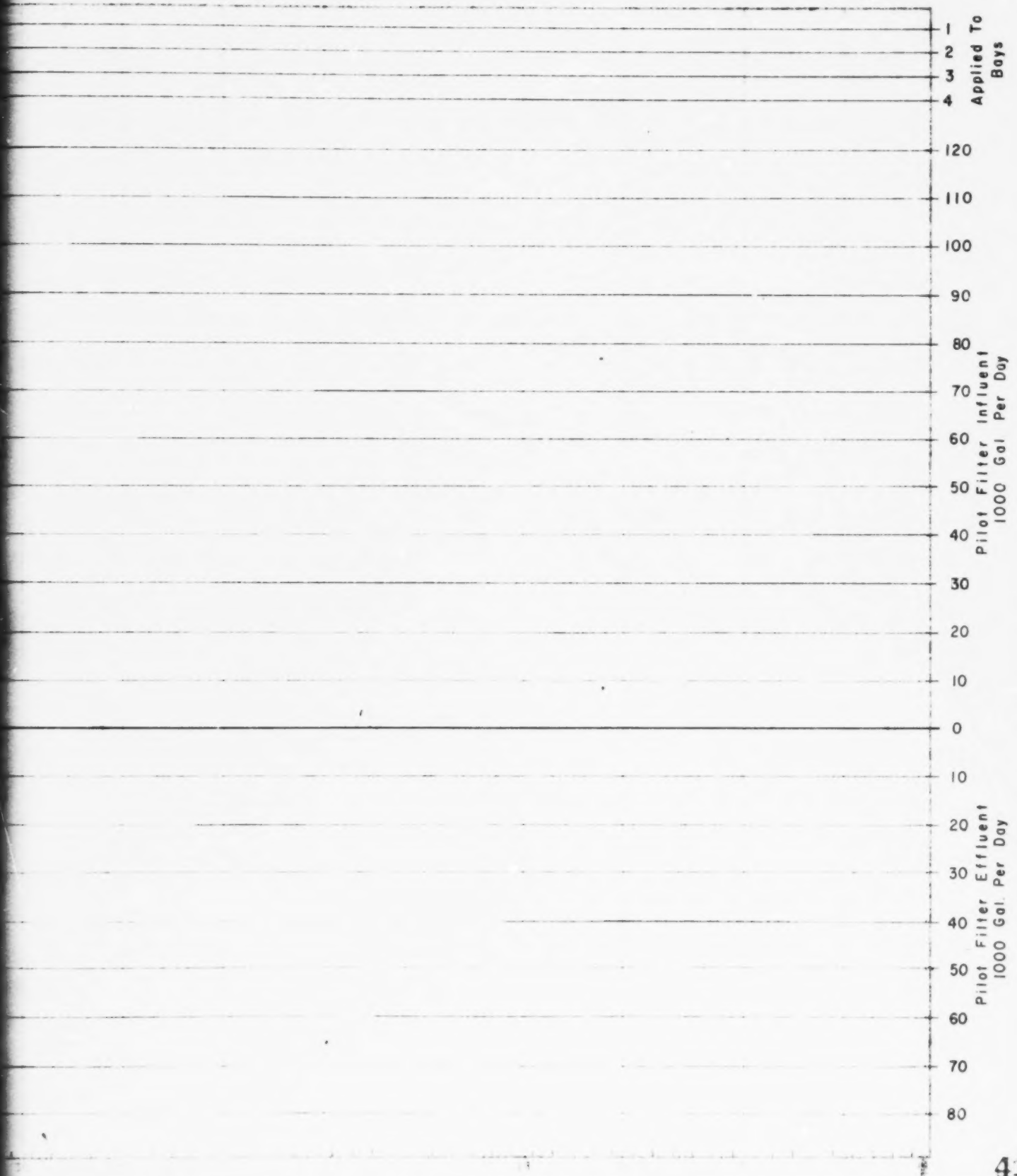
B

C

RECLAMATION PROJECT and Performance

PLATE 8

4TH QUARTER - YR 03



CHAPTER IV

CHEMISTRY

1. INTRODUCTION

The Pilot Filter was readied for operation by May of 1966 at which time it was thought best to pretreat the filter media to an extensive period of flushing in order to remove any excessive concentrations of atypical salts which may have been incorporated in the media during mechanical spreading operations. The media had been acquired from natural river wash materials in the Santa Cruz flood plain. The foregoing flushing operation was accomplished by flooding the basins progressively with secondary activated sludge effluent until the Electro-Conductance measurements of inflow and outflow had stabilized. Chloride equilibriums were also measured and quite closely reflected the Electro-Conductance stabilization.

2. THE PROBLEM

From the chemical aspect of project activities, the following questions are most paramount:

- A. What is the chemical quality of the source water to the project Pilot Filter.
- B. What is the chemical quality of the Pilot Filter effluent waters derived from the various phases of filter operation including intrafilter water quality.
- C. What is the chemical quality of Pilot Filter effluent waters derived from passage thru experimental fish ponds as compared with the effluent from the Pilot Filter operation. (Thus, what effect could be observed with 10-20 days detention).

- D. What chemical qualities of Pilot Filter effluent would be acceptable for a full scale Project Filter.

3. METHOD OF ANALYSIS

Wet chemistry, spectro- and flame photometry, were performed in accordance with "Standard Methods of Analysis for Water & Wastewater", 11th edition. All samples were collected in one or two liter, widemouthed polyethylene bottles with screw tops and stored at 4° C. but not before pH, ORP, EC and bicarbonate alkalinity were determined. All determinations relating to the nitrogen spectra (NH₃-N, NO₂-N, NO₃-N, total organic nitrogen and organic nitrogen) were performed within a 24-hour period on non-acidified samples from refrigerator storage. Since the waters under examination were relatively alkaline, no disturbance in nitrite and nitrate balance was expected during these short periods of storage before analysis.

Individual reporting of ions were, in general, rounded off to one decimal point and total nitrogen was reported to the nearest whole number.

4. PHASED PILOT FILTER OPERATION

In order to test the efficiency of horizontal travel in the clean up (chemical) of secondary sewage effluent, the basins were loaded first to provide to longest possible intrafilter travel and later loaded at different loci to test the effect of decreasing the travel distance as well as increasing the volume of effluent to be derived. A later deviation also included the monitoring of chemical quality

derived as a result of purely vertical pumpage (surface to effluent approximately twenty feet).

The quality of the source water to be utilized for testing the removal efficiencies of the Pilot Filter was of prime consideration and, therefore, a rather complete chemical analysis of this water was necessary. It was decided that the best source of secondary wastewater would be that derived from the activated sludge process and a chemical analysis of this water was accomplished thru a 24-hour composite sampling program and an actual every four (4) hour analysis of the activated sludge effluent for a period of twenty-four (24) hours. The composite sample characterized that effluent and the twenty-four hour, every four hour program indicated the periods of highest quality. The daily loadings of the Pilot Filter would then be geared to the most desirable effluent quality. (Less B.O.D., fewer solids, less chloride, less phosphate, etc.)

Included at this time in the report is Table 1, a chemical characterization of the Tucson Wastewater Treatment Plant Secondary Activated Sludge Effluent (ASE), for twenty-one months (July 1966 thru March 1968). A selected chemical characterization of the TWTP-ASE over a period of 24 hours was presented in TWRP annual report of 1966.

The first phase of Pilot Filter operation utilized the greatest travel distance available and was operational, from a controlled monitoring standpoint, from June thru December of 1966. See Plates 1 and 2, Chap. III (Bay loaded, vol, influent, vol. effluent).

TUCSON WA
MONTHLY CHEM
SECONDARY
JULY

MONTH - 7 ppm's	1966						1967						A
	8	9	10	11	12		1	2	3	4	5	6	
DS	638	583	645	601	601	612	602	654	745	661	699	747	6
SS	19	7	23	57	31	28	94	35	14	37	22	15	3
FS	556	453	543	547	495	510	466	563	644	582	559	610	5
VS	101	137	125	112	137	130	230	126	115	116	162	152	1
pH	7.5	7.7	7.9	-	7.9	8.0	-	7.8	8.0	8.0	8.0	7.9	7
BOD	24	16	42	18	51	24	24	22	23	22	26	16	2
COD	-	-	-	-	-	-	-	-	-	-	-	-	
NH ₃ -N	22.7	24.1	24.1	28.0	34.2	30.8	29.7	21.3	28.0	23.2	24.6	23.1	2
NO ₂ -N	0.04	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	T	0
NO ₃ -N													
ORG-N	5.0	5.9	6.0	8.9	12.3	3.9	2.8	5.6	8.8	7.3	6.2	4.2	6
Ca	70	-	48	76	46	60	46	66	53	66	49	59	5
Mg	14	18	17	18	23	21	18	19	16	15	21	17	1
Cl	86	88	74	93	90	86	96	85	91	106	98	86	9
CO ₃	0	0	0	0	0	0	0	0	0	0	0	0	0
HCO ₃	320	327	341	356	346	356	395	357	364	395	342	344	3
PO ₄	-	28	15	26	48	26	36	49	36	37	33	22	3
SO ₄	166	167	115	155	130	123	138	138	145	171	161	146	1

* E. J. Trueblood, Chief Chemist (TWTP)

X

TABLE I
TUCSON WASTEWATER TREATMENT PLANT *
MONTHLY CHEMICAL ANALYSES (24 HR. COMPOSITE)
SECONDARY ACTIVATED SLUDGE EFFLUENT
JULY 1966 THRU MARCH 1968

1967				F/Y		1967						1968			AVG
3	4	5	6			7	8	9	10	11	12	1	2	3	
745	661	699	747	649	(645)	-	-	666	595	534	632	550	-	-	595
14	37	22	15	32	(23)	-	8	28	34	38	47	31	-	50	34
644	582	559	610	544	(547)	642	-	543	486	478	594	434	468	-	520
115	116	162	152	137	(126)	-	-	123	109	56	38	116	-	-	88
8.0	8.0	8.0	7.9	7.9	(7.9)	-	7.9	7.8	-	7.8	7.7	7.7	-	-	7.8
23	22	26	16	26	(23)	14	13	28	32	32	27	29	30	-	26
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28.0	23.2	24.6	23.1	26.2	(24.1)	20.2	33.0	22.4	30.2	24.1	21.6	22.4	23.2	23.0	24.
0.00	0.00	0.00	T	0.0	(0.0)	0.00	0.003	0.013	0.002	0.016	0.007	0.012	0.017	-	0.0
8.8	7.3	6.2	4.2	6.4	(5.9)	3.9	3.9	7.8	11.8	10.1	6.2	6.7	7.8	3.4	6.0
53	66	49	59	58	(59)	74	-	-	77	73	55	55	58	-	65
16	15	21	17	18	(18)	18	17	-	18	16	10	12	12	-	15
91	106	98	86	90	(88)	112	104	92	76	80	90	-	74	84	89
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
364	395	342	344	354	(346)	327	381	307	366	317	312	327	249	312	32
36	37	33	22	32	(33)	34	23	34	24	-	-	-	52	35	34
145	171	161	146	146	(145)	146	150	-	147	160	103	143	144	-	14

B

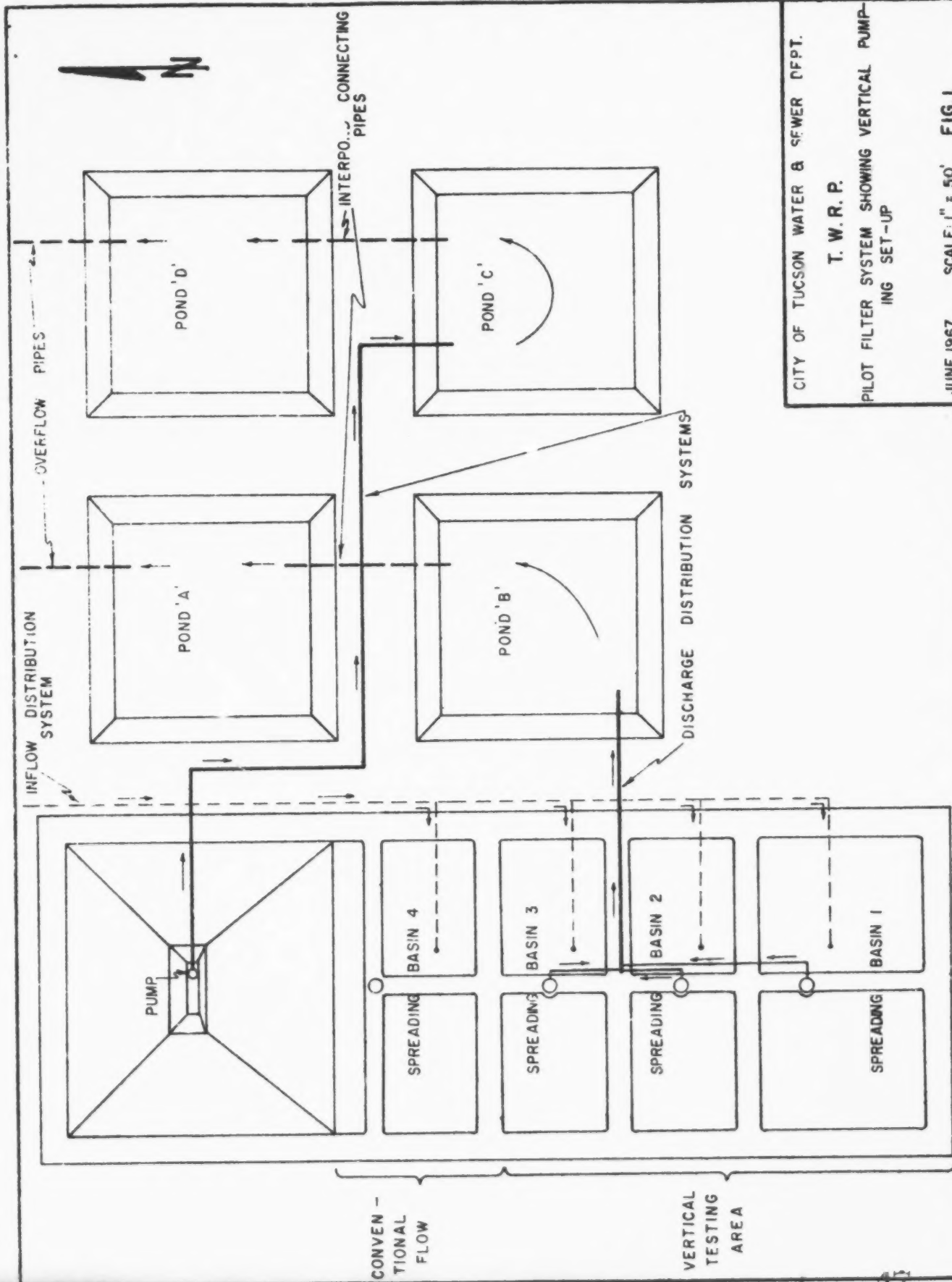
WATER PLANT *
 (MONTHLY COMPOSITE)
 EFFLUENT
 1968

	1967					1968			F/Y		COMPOSITE AVERAGES	
	8	9	10	11	12	1	2	3	AVG.	MEDIAN	AVG.	MEDIAN
	-	666	595	534	632	550	-	-	595	(595)	622	620
	8	28	34	38	47	31	-	50	34	(34)	33	29
2	-	543	486	478	594	434	468	-	520	(486)	532	517
	-	123	109	56	38	116	-	-	86	(109)	113	118
	7.9	7.8	-	7.8	7.7	7.7	-	-	7.8	(7.8)	7.9	7.8
	13	28	32	32	27	29	30	-	26	(26)		
	-	-	-	-	-	-	-	-	-	-	-	-
0.2	33.0	22.4	30.2	24.1	21.6	22.4	23.2	23.0	24.5	(23.0)	25.4	23.6
00	0.003	0.013	0.002	0.016	0.007	0.012	0.017	-	0.009	(0.007)		
9	3.9	7.8	11.8	10.1	6.2	6.7	7.8	3.4	6.8	(6.7)	6.6	6.3
	-	-	77	73	55	55	58	-	65	(58)	62	59
	17	-	18	16	10	12	12	-	15	(16)	17	17
12	104	92	76	80	90	-	74	84	89	(84)	90	86
	0	0	0	0	0	0	0	0	0	0	0	0
27	381	307	366	317	312	327	249	312	322	(317)	338	332
4	23	34	24	-	-	-	52	35	34	(34)	33	34
46	150	-	147	160	103	143	144	-	142	(146)	144	146

Phase Two (2) began in January of 1967 and terminated in April of the same year. This operation moved the influent water to the Pilot Filter midpoint, thus shortening the horizontal travel to the effluent collection area. This is referred to as the Bay #3 operation as opposed to the initial operation from Bay #1.

See Plates 3 and 4, Chapter III.

After Bay #3 operations were terminated, the Technical Planning Committee decided to investigate the possibilities of vertical filtration as an adjunct to vertical-horizontal operation. Thus, in May of 1967, considerable time was spent on the reworking of the CMP's in Bays #1, 2, and 3, to accommodate new piping, centrifugal pumps, and metering devices to collect and measure pilot filter waters as they were discharged into the wells from the lowest open lines beneath each Bay concerned. Intermittent pumping was controlled by liquid level electrodes and the collected effluents were discharged into Pond B. (See Figures 1 and 2.) Operations were begun in June of 1967 and continued until October of 1967. By the end of October, thru an alteration in the piping system, vertical pumpage was being equally distributed to both Ponds B and C. (See Fig. 3). During this same period, flooding of all four (4) Bays was accomplished on a demand basis with interconnection of all Bay influent piping so as to maintain equal water levels everywhere. Pilot Filter effluent water was still proceeding to normal effluent collection from Bay #4 and this effluent was turned into Pond C for further observation and analysis. At the end of October, the PFE began to be distributed equally to Ponds B and C.



CITY OF TUCSON WATER & SEWER DEPT.

T. W. R. P.

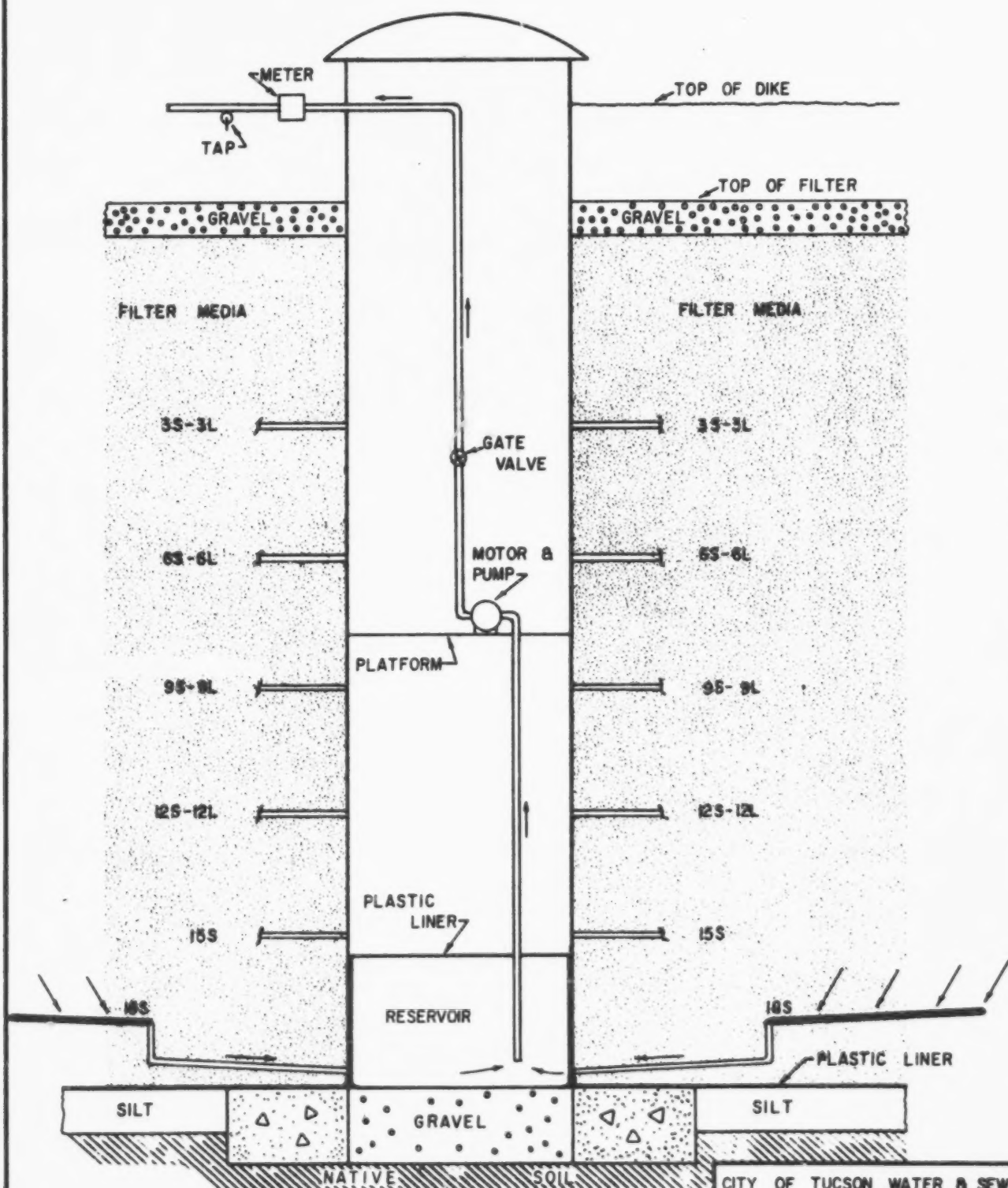
PILOT FILTER SYSTEM SHOWING VERTICAL PUMP-
ING SET-UP

JUNE 1967

SCALE: 1" = 50'

FIG. 1

CROSS SECTIONAL VIEW OF VERTICAL PUMPING SET-UP IN C.M.P.

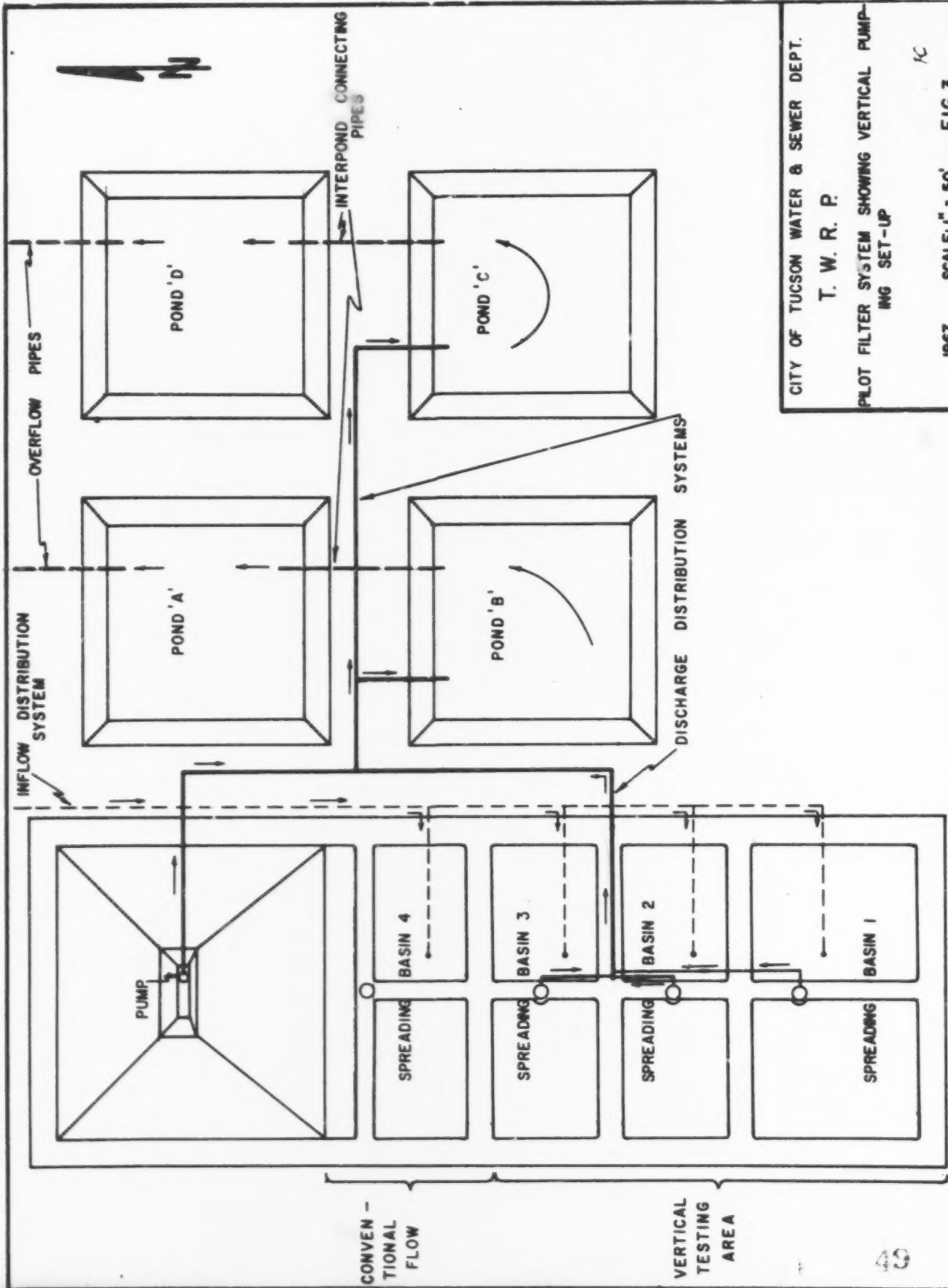


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T. W. R. P.

48

SCALE: 1" = 30' FIG. 2



CITY OF TUCSON WATER & SEWER DEPT.

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PLOT FILTER SYSTEM SHOWING VERTICAL PUMP-
ING SET-UP

KC

1967 SCALE: 1" = 50' FIG. 3

The last phase of the present report began in December of 1967 and utilized again Bay #3 loading, which continued to supply water to the fish ponds which had now been populated to determine fish stocking rates and environmental factors regarding survival.

In March of 1967, analyses of surface waters in the Bays of the Pilot Filter indicated a removal phenomenon not previously contemplated in the operation of the tertiary filter and modifications in sampling procedures were instituted to acquire data on the chemical profile of these waters after twenty (20) hours had elapsed since the last loading to the Pilot Filter. That is to say, load the filter surface, and sample that surface twenty-four hours later, and then relate this quality to the PFI and then the PFE from whatever source.

The quality of water within the filter was not the least important aspect of the Project, because it would be of interest to know what removals had occurred after some certain length of detention or travel within the filter itself. The intrafilter sampling points were utilized in every filter operation phase to determine the chemical character of these waters in vertical and horizontal passage to an effluent collection source.

5. CHEMISTRY OF PHASED OPERATIONS

Phase I

The Pilot Filter Influent (PFI), during the period under consideration, had an average total nitrogen (all sources) concentration of 32 parts per million as N. (Table 2). A visual analysis of the table

TABLE 2
NITROGEN CONSTITUENTS PFI
(BAY #1 OPERATION)

1966	NH ₃ -N	NO ₂ -N	NO ₃ -N	ORG-N	T-K ₁ -N	T-N
Aug. 22	24.1	-	-	5.9	30.0	(30.0) +
Sep. 14	25	-	1.8	-	-	(32) *
16	40	-	1.4	-	-	(46) *
19	44	-	-	-	-	(49) *
21	33	-	0.0	-	-	(38) *
26	35	-	0.1	-	-	(40) *
27	24.1	-	-	6.0	30.1	(30) +
28	28	-	1.4	-	-	(34) *
Oct. 4	30	-	0.9	-	-	(36) *
6	23	-	0.0	-	-	(28) *
10	23	-	0.0	-	31	31
12	25	-	0.3	-	27	27
17	(31)	-	0.1	-	29	29
19	39	-	-	-	-	(44) *
29	28	-	-	8.9	36.9	(37) +
Nov. 14	23	-	0.1	-	-	(28) *
15	34.2	-	-	12.3	46.5	(47) +
28	23	-	-	-	26	26
29	20	-	0.3	-	-	(25) *
Dec. 5	23	-	0.4	-	28	28
12	23	-	0.1	-	27	27
14	30.8	-	-	3.9	34.7	(35) +
19	28	-	0.1	-	31	31
<u>1967</u>						
Jan. 4	29.7	-	-	2.8	32.5	(33) +

() = Adjusted figure

* = 5 ppm ORG-N added when no K₁-N or ORG-N available

+ = Tucson Sewage Treatment Plant composite effluent

indicates that the nitrogen present is not stable, being mainly in the form of ammonia - N. This type of effluent from a sewage treatment plant would therefore have a specific B.O.D. higher than that suitable for a fresh water lake in which oxygen levels might be important, but, further, the ammonia nitrogen would prove toxic to a trout fishery unit as is contemplated.

The range of ammonia nitrogen is 20 to 44 parts per million and stable nitrate nitrogen 0 to 1.8 during the period. Nitrite was not determined routinely as its concentration was negligible for a balance figure, usually less than 0.05 of a ppm.

The Pilot Filter Effluent (PFE) chemical quality as is related to the influent is quite striking and obviously removals have been effected in the 250 foot passage within the filter itself. Ammonia nitrogen has disappeared to levels of less than 0.1 of a part per million on the average and total nitrogen from all sources has been reduced to an average of approximately 5 ppm, thus indicating removal of approximately 86% of the nitrogenous pollutants originally given to the surface of the filter. Table 3, Biochemical Oxygen Demand, has dropped precipitously also while a substantial reduction in the C.O.D. is evident. (See Sanitary Engineering section.)

Not only, then, have the total nitrogen levels been reduced, but their ratios as to individual forms has changed. Whereas ammonia-nitrogen was more than 75% of the PFI water, now that level has slipped to practically zero. Conversely, nitrate-nitrogen represented approximately 0.03% of the total PFI nitrogen and now

TABLE 3
NITROGEN CONSTITUENTS PFE
(BAY #1 OPERATION)

1966	NH ₃ -N	NO ₂ -N	NO ₃ -N	ORG-N	T-K _j -N	T-N
Sep. 14	0.1	0.1	4.4	-	(2.0)	(6.5)
16	2.0	0.1	6.1	-	(2.0)	(8.2)
19	0.1	-	(5.0)	-	3.0	(8.0)
21	0.1	0.1	5.4	-	(2.0)	(6.5)
27	2.0	0.2	6.1	-	2.0	8.3
29	0.0	1.0	6.8	-	2.8	10.6
Oct. 4	0.0	0.1	2.9	-	(2.0)	(5.0)
6	0.0	0.4	2.3	-	1.1	3.8
11	0.1	0.0	1.6	-	1.4	3.0
13	0.1	0.1	1.8	-	(2.0)	(3.9)
18	0.1	0.1	2.5	-	(2.0)	(4.6)
20	0.0	0.1	-	-	-	-
Nov. 14	0.1	0.1	0.2	-	(2.0)	(2.3)
15	0.4	0.0	-	-	-	-
28	0.0	0.0	0.3	-	1.7	2.0
29	0.0	0.1	0.8	-	(2.0)	(2.9)
Dec. 5	0.0	-	1.2	-	1.0	2.2
12	0.0	-	2.3	-	1.4	3.7
19	0.0	-	3.1	-	2.2	5.3

() = Adjusted figure

* = 5 ppm ORG-N added when no K_j-N or ORG-N available

+ = Tucson Sewage Treatment Plant composite effluent

risen to between 20-80% of the PFE total nitrogen (Average 60%).

Intrafilter removals of $\text{NH}_3\text{-N}$ during this phase are vital and are graphically represented in Figure 4. Like removals were also observed in the cases of B.O.D. and C.O.D. in Figure 5. An understanding of the mechanism for horizontal removals of polluting substances has not been explained as yet, but it would be misleading to attribute removals that appear to be vertical in declination to a pure vertical flow since the vertical factor is negligible in a saturated, contained, filter trough with only one effluent outlet in a fixed vector.

Phase II

During this period of operation, from a Bay #3 position the productive capacity of the filter based on total gallonage per day to effluent more than doubled as compared to the Bay #1 activity. (Plates 3 & 4) The data clearly indicates, on the basis of total nitrogen, that the apparent removals were still greater than 80% between PFI and PFE. (See Tables 4 & 5) On the surface of the matter, it might be said that the operational change did very little to affect the quality of the final product, but reality changes that conception. If twice plus as much influent is being applied to this Bay, then approximately twice the amount of total N is being removed.

A polluting factor that previously was of little significance in the effluent (PFE) was on the increase by some 300+ %. Ammonia nitrogen that had been either absent or in less than 0.1 part per million showed an increase to an average of 0.4 ppm during the

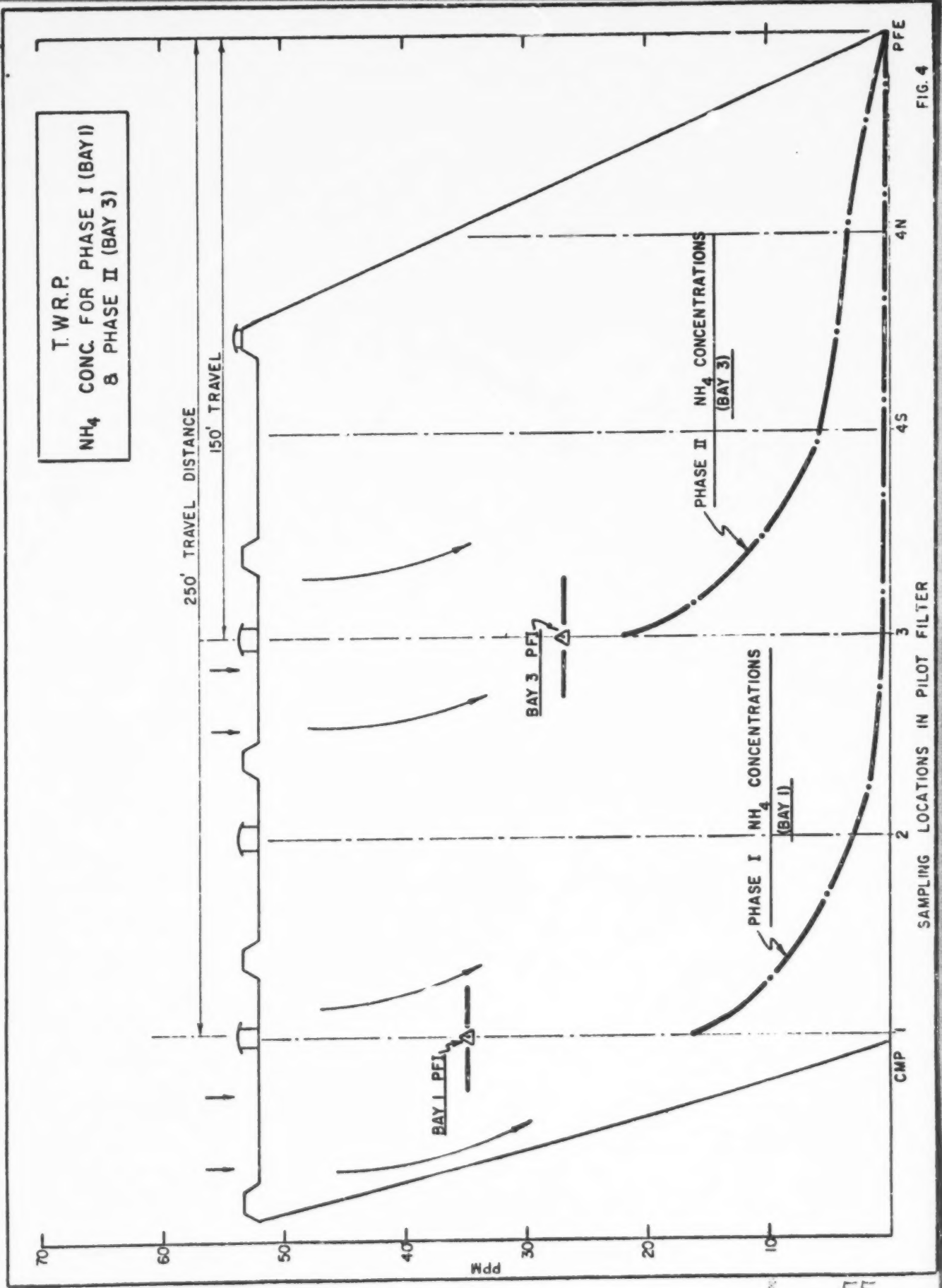


FIG. 4

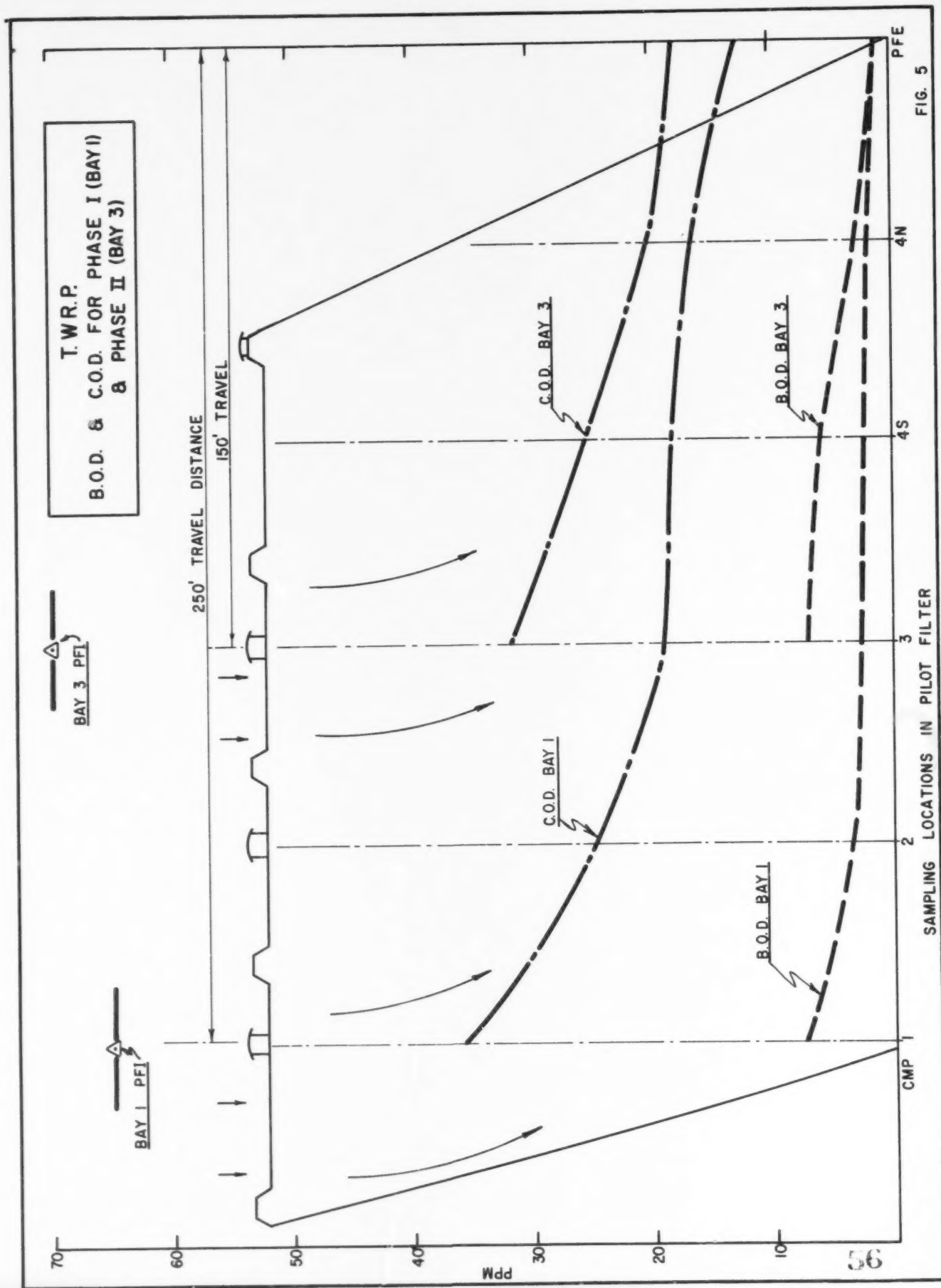


FIG. 5

TABLE 4
NITROGEN CONSTITUENTS PFI
(BAY #3 OPERATION)

1967	NH ₃ -N	NO ₂ -N	NO ₃ -N	ORG-N	T-K _j -N	T-N
Jan. 10	31	-	0.1	-	31	31
16	21	-	0.1	-	38	38
17	21	-	0.2	-	38	38
20	20	-	0.1	-	-	(25) *
23	22	-	0.1	-	33	33
31	30	-	0.1	-	29	29
Feb. 1	31	-	0.0	-	26	26
2	20	-	0.1	-	24	24
3	22	-	0.1	-	26	26
6	19	-	0.1	-	23	23
7	20	-	0.0	-	26	26
11	21.3	-	-	5.6	26.9	(27) +
13	13	-	0.1	-	29	29
27	24	-	0.1	-	24	24
28	18	-	0.2	-	26	26
Mar. 1	22	-	0.2	-	26	26
2	18	-	0.5	-	16	17
6	22	-	0.2	-	35	35
8	-	-	-	-	27	27
10	-	-	-	-	31	31
11	28	-	-	8.8	36.8	(37) +
Apr. 10	24.1	-	-	1.4	25.5	(26) +

() = Adjusted figure

* = 5 ppm ORG-N added when no K_j-N or ORG-N available

+ = Tucson Sewage Treatment Plant composite effluent

TABLE 5
NITROGEN CONSTITUENTS PFE
(BAY #3 OPERATION)

1967	NH ₃ -N	NO ₂ -N	NO ₃ -N	ORG-N	T-K _j -N	T-N
Jan. 10	1.0	-	5.7	-	0.8	6.5
17	1.4	-	1.8	-	2.8	4.6
20	0.0	-	1.0	-	(3.0)	(4.0)
23	1.5	-	0.8	-	3.1	3.9
24	0.0	-	0.8	-	5.3	6.1
31	0.4	-	2.0	-	2.6	4.6
Feb. 1	0.1	-	1.6	-	2.2	3.8
2	-	-	1.7	-	1.4	3.1
3	0.4	-	1.3	-	1.7	3.0
6	0.2	-	1.2	-	2.8	3.0
7	0.6	-	1.3	-	3.4	4.7
13	0.6	-	2.7	-	1.2	3.9
20	-	-	(3.0)	-	2.5	(5.5)
27	0.0	-	3.9	-	3.6	7.5
28	0.2	-	3.6	-	3.6	7.2
Mar. 1	0.2	-	3.2	-	4.2	7.4
2	0.1	-	3.6	-	1.4	5.0
6	0.3	-	4.1	-	(3.0)	(7.1)
Apr. 27	-	-	5.7	-	4.5	10.2

() = Adjusted figure

* = 5 ppm ORG-N added when no K_j-N or ORG-N available

+ = Tucson Sewage Treatment Plant composite effluent

Phase II period. Chemically and aesthetically this amount plays no role, but it would increase the B.O.D. and as regards fish susceptibility to this amount it might be classified as slightly toxic.

Phase III

During this period three activities were carefully observed: (As to pollutant removals)

1. Nitrogen removals in surface waters of Pilot Filter after 20 hours of detention (Quality).
2. Nitrogen removals due to the institution of vertical pumpage from the lowest lines (open) in CMP's Nos. 1, 2, and 3.
3. Nitrogen removals at the Pilot Filter effluent (PFE) from a continuing Bay #4 operation.

This phase of the operation called for the continuous loading of all surface bays to the filter (4) and a strict observance of the chemical quality (nitrogenous) of the influent and effluent from the various sectors under observation, as well as monitoring of the surface phenomenon.

Chemical observation of the effect of detention (20 hours after filling) at the filter surface had proceeded intermittently from March 1967 until the beginning of this phase, and had indicated apparent removal of nitrogenous constituents at the surface. Table 6 presents the average nitrogen spectra of the PFI surface waters after this 20 hours of detention and includes data from a period of

TABLE 6
NITROGEN CONSTITUENTS
PFI - AFTER 20 HR.
SURFACE DETENTION
(BAY #1)

1967	NH ₃ -N	NO ₂ -N	NO ₃ -N	ORG-N	T-K ₁ -N	T-N
Aug. 8	1.0	-	0.1	-	5.3	5.4
14	0.5	-	0.1	-	7.8	7.9
Sep. 6	-	-	0.1	-	5.6	5.7
13	1.0	0.2	0.2	-	10.6	11.0
14	1.0	0.3	0.1	-	8.4	8.8
15	1.5	0.2	0.3	-	10.6	11.1
Oct. 2	1.0	0.1	0.2	-	8.4	6.7
4	1.0	0.1	0.2	-	10.4	10.7
5	2.0	0.1	0.2	-	11.0	11.4
6	1.0	0.1	0.2	-	8.7	9.0
9	1.0	0.2	0.2	-	10.6	11.0
10	3.0	0.1	0.2	-	14.8	15.1
11	6.0	0.2	0.2	-	10.6	11.0
13	1.0	0.1	0.2	-	6.2	6.5
Nov. 6	10.0	0.1	0.5	-	20.4	21.0
7	17.0	0.1	1.0	-	24.0	25.1
9	13.0	0.1	0.2	-	21.0	21.3
10	12	0.1	0.2	-	20.7	21.0
13	0.5	0.1	0.5	-	10.9	11.5
14	0.5	0.1	0.1	-	22.7	22.9
15	7.0	0.2	0.1	-	16.8	17.1
16	7.0	0.1	0.1	-	19.8	20.0
21	15.0	0.1	0.1	-	19.6	19.8
22	10.0	0.1	0.1	-	21	21.2

() = Adjusted figure

* = 5 ppm ORG-N added when no K₁-N or ORG-N available

+ = Tucson Sewage Treatment Plant composite effluent

Pilot Filter surface manipulation. Comparison of these values to the average influent to the Pilot Filter during this period (Tables 7, 8, & 9) would indicate more than 50% removal of nitrogen before tertiary treatment PFE for the period is presented in Tables 10, 11 & 12.

Vertical pumpage from the three CMP's was averaged as to chemical quality and reported in Table 13. Compared to average PFI nitrogen concentration, a clear demonstration of more than 65% removal is obtained. The dissolved oxygen (D.O.) in the effluent of this operation is negligible (less than 0.5 ppm), and $\text{NH}_3\text{-N}$ was present in considerable quantity (Range 1-10 ppm). (See composite Table of Phased Operations which is included later in the text.)

Phase IV

The return to a Bay #3 operation at this juncture (mid December 1967 to present) served as a repeat of the earlier Phase II operation. During this period (IV) Pilot Filter influent total nitrogen ranged between 22-34 ppm. (Table 14). Vertical pumpage at CMP #1 was reactivated to dry the surface thereof for cleanup and manipulation to establish a different Bay surface for future testing. The quality of PFI was under intermittent monitoring to determine the nitrogen content of the surface of the Pilot Filter during this "no removal" period. Removals began again on about the first of April, 1968, and are continuing at this time to average about 50% of the incoming N in secondary activated sludge effluent (ASE). (Table 15).

TABLE 7
NITROGEN CONSTITUENTS PFI
VERTICLE PUMPAGE
(BAY #4 OPERATION-ALL)

1967	NH ₃ -N	NO ₂ -N	NO ₃ -N	ORG-N	T-K _j -N	T-N
June 4	25.2	-	-	3.9	29.1	(29) +
8	-	-	-	-	26	26
15	25.4	-	0.2	-	26	26
21	21.8	-	-	4.5	26.3	(26) +
July 5	20.2	-	-	3.9	24.1	(24) +
Aug. 2	-	-	-	-	20	20
7	20	-	0.2	-	28	28
8	18	-	0.2	-	25	25
9	15	-	0.2	-	27	27
10	14	-	0.2	-	25	25
11	22	-	0.2	-	26	26
14	15	-	0.2	-	18	18
15	18	0.1	0.2	-	22	22
16	17	0.1	0.2	-	22	22
18	15	0.1	0.2	-	22	22
Sep. 5	4	0.4	0.2	-	16	17
6	-	-	-	-	19	19
7	-	-	-	-	22	22
8	12	0.3	0.2	-	23	24
13	16	-	0.2	-	22	22
14	20	0.5	0.5	-	22	23
28	22.4	-	-	7.8	(30.2)	(30) +
Oct. 2	18	0.1	0.2	-	22	22
4	15	0.1	0.2	-	20	20
6	10	0.1	0.2	-	22	22

() = Adjusted figure

* = 5 ppm ORG-N added when no K_j-N or ORG-N available

+ = Tucson Sewage Treatment Plant composite effluent

TABLE 8
NITROGEN CONSTITUENTS PFI
VERTICLE PUMPAGE
(BAY #3 OPERATION)

1967	NH ₃ -N	NO ₂ -N	NO ₃ -N	ORG-N	T-Kj-N	T-N
Oct. 10	16	0.5	0.2	-	22	23
13	5	0.2	-	-	29	29
31	30.2	-	-	11.8	42	42

() = Adjusted figure

* = 5 ppm ORG-N added when no Kj-N or ORG-N available

+ = Tucson Sewage Treatment Plant composite effluent

TABLE 9
NITROGEN CONSTITUENTS PFI
VERTICLE PUMPAGE
(BAY #4 OPERATION)

1967	NH ₃ -N	NO ₂ -N	NO ₃ -N	ORG-N	T-K _j -N	T-N
Nov 6	-	-	-	-	68	68
10	16	-	-	-	21	21
13	2	-	0.1	-	24	24
14	12	-	0.2	-	25	25
20	10	-	0.1	-	29	29
27	24.1	-	-	10.1	34.2	34 +

() = Adjusted figure

* = 5 ppm ORG-N added when no K_j-N or ORG-N available

+ = Tucson Sewage Treatment Plant composite effluent

TABLE 10
NITROGEN CONSTITUENTS PFE
VERTICLE PUMPAGE
(BAY #4 OPERATION-ALL)

1967	NH ₃ -N	NO ₂ -N	NO ₃ -N	ORG-N	T-K _j -N	T-N
June 6	0.4	-	3.2	-	(3.0)	(6.2)
8	1.4	-	3.2	-	3.4	6.6
15	2.2	-	3.5	-	3.4	6.9
22	1.2	-	4.5	-	3.0	7.5
29	0.8	-	3.8	-	(3.0)	(6.8)
July 13	0.4	-	5.4	-	(3.0)	(8.4)
Aug. 2	1.5	-	4.5	-	6.4	10.9
7	0.1	-	4.2	-	6.7	10.9
8	0.1	-	4.0	-	6.4	10.4
9	1.8	-	4.4	-	6.4	10.8
10	0.8	-	4.2	-	6.7	10.9
11	0.1	-	4.0	-	6.4	10.4
14	0.4	-	4.4	-	8.4	12.8
15	1.6	0.3	4.3	-	5.6	10.2
16	0.8	0.2	4.2	-	6.4	10.8
17	0.4	0.1	4.0	-	5.8	9.9
18	0.4	0.3	4.2	-	5.9	10.4
Sep. 5	0.5	0.1	4.0	-	5.6	9.7
6	-	-	(4.0)	-	6.2	(10.2)
7	1.0	0.4	3.8	-	7.3	11.5
8	0.5	0.3	4.0	-	5.3	9.6
12	0.5	0.3	4.2	-	5.3	9.8
13	1.0	0.3	4.0	-	5.6	9.9
14	1.0	0.3	4.1	-	5.3	9.7
15	0.5	0.3	4.5	-	5.3	10.1
Oct. 2	0.1	0.3	3.8	-	5.6	9.7
4	0.5	0.3	4.0	-	5.0	9.3
5	0.5	0.3	4.1	-	6.2	10.6
6	0.1	0.3	4.0	-	6.7	11.0

() = Adjusted figure

* = 5 ppm ORG-N added when no K_j-N or ORG-N available

+ = Tucson Sewage Treatment Plant composite effluent

TABLE 11
NITROGEN CONSTITUENTS PFE
VERTICLE PUMPAGE
(BAY #3 OPERATION)

1967	NH ₃ -N	NO ₂ -N	NO ₃ -N	ORG-N	T-K _j -N	T-N
Oct. 9	0.0	0.3	4.0	-	3.9	8.2
10	0.0	0.2	3.6	-	5.8	9.6
13	0.5	0.2	(4.0)	-	4.8	(9.0)
Nov. 3	0.1	0.2	-	-	-	-

- () = Adjusted figure
 * = 5 ppm ORG-N added when no K_j-N or ORG-N available
 + = Tucson Sewage Treatment Plant composite effluent

TABLE 12
NITROGEN CONSTITUENTS PFE
VERTICLE PUMPAGE
(BAY #4 OPERATION)

1967	NH ₃ -N	NO ₂ -N	NO ₃ -N	ORG-N	T-K _j -N	T-N
Nov. 6	0.1	0.2	3.0	-	9.0	12.2
7	1.5	2.0	10.5	-	3.9	16.4
9	1.0	0.1	10.0	-	4.5	14.6
10	1.5	0.1	(3.0)	-	4.5	(12.6)
13	2.0	-	3.5	-	3.9	7.4
14	1.5	-	3.0	-	4.5	7.5
15	0.1	0.3	(3.0)	-	7.8	(11.1)
16	0.5	-	3.8	-	3.4	7.2
20	0.0	0.4	2.5	-	2.8	5.7
21	0.5	-	2.5	-	2.5	5.0
22	0.2	0.4	(3.0)	-	2.2	(5.6)

() = Adjusted figure

* = 5 ppm ORG-N added when no K_j-N or ORG-N available

+ = Tucson Sewage Treatment Plant composite effluent

TABLE 13

TOTAL NITROGEN IN VERTICAL PUMPAGE
CMP EFFLUENT - AVERAGE CONCENTRATIONS ppm
(1, 2, and 3 combined)

1967	NH ₃ -N	NO ₂ -N	NO ₃ -N	K _j -N	T-N (ppm)
May 17	-	-	3.9	4.9	8.8
18	-	-	3.7	6.8	10.5
31	3.6	-	2.0	5.6	7.6
June 6	8.0	-	0.3	8.2	8.5
8	8.1	-	0.1	8.3	8.4
15	7.5	-	0.2	8.2	8.4
Aug. 7	3.6	-	0.2	8.5	8.7
8	7.5	-	0.2	8.0	8.2
9	6.0	-	0.1	7.7	7.8
10	4.0	-	0.2	7.8	8.0
11	3.0	-	0.1	8.5	8.6
14	2.0	-	0.2	10.6	10.8
15	3.2	0.2	0.2	7.6	8.0
16	4.0	0.1	0.2	9.3	9.6
Sep. 5	2.0	0.1	0.2	7.2	7.5
6	-	-	0.2	7.4	7.6
7	1.6	0.2	0.2	8.6	9.0
8	1.0	0.2	0.2	7.3	7.7
13	2.0	0.1	0.2	7.1	7.4
14	2.3	0.0	0.2	7.7	7.9
15	2.7	-	0.2	7.1	7.3

TABLE 14
NITROGEN CONSTITUENTS PFI
DISCONTINUOUS VERTICLE PUMPAGE
(BAY #3 OPERATION)

1967-68	NH ₃ -N	NO ₂ -N	NO ₃ -N	ORG-N	T-K ₁ -N	T-N
Dec. 13	16	-	-	-	30	30
14	19	-	-	-	32	32
18	18	-	0.2	-	27	27
19	21.6	-	-	6.2	27.8	28 +
28	16	-	-	-	34	34
1968 Jan. 2	-	-	0.2	-	24	24
8	-	-	0.1	-	23	23
9	-	-	0.1	-	25	25
10	-	0.1	0.1	-	24	24
16	-	-	-	-	22	22
18	-	-	-	-	24	24
22	22.4	-	-	6.7	29.1	29 +
Feb. 18	23.2	-	-	7.8	31	31 +
Mar. 28	23.0	-	-	3.4	26.4	26 +
29	-	0.1	0.2	-	28.3	29
Apr. 2	-	0.1	0.2	-	21.6	22
4	-	-	-	-	24.6	25
8	-	-	0.3	-	29.4	30
11	-	-	0.2	-	27.4	28
12	-	-	0.2	-	34.2	34
15	-	-	0.1	-	24.5	25

() = Adjusted figure

* = 5 ppm ORG-N added when no K₁-N or ORG-N available

+ = Tucson Sewage Treatment Plant composite effluent

TABLE 15
NITROGEN CONSTITUENTS
PFI - AFTER 20 HR.
SURFACE DETENTION
(BAY #3)

1967-68	NH ₃ -N	NO ₂ -N	NO ₃ -N	ORG-N	T-K _j -N	T-N
Dec. 18	12	-	0.0	-	25.2	25
1968						
Jan. 2	11	-	0.1	-	24.4	25
9	7	-	0.2	-	24.1	24
15	1.5	-	1.0	-	23.2	24
Mar. 28	-	0.4	0.3	-	25.4	26
29	-	1.0	0.5	-	22.4	24
Apr. 1	-	2.8	1.9	-	19.9	25
2	-	2.5	1.5	-	14.3	18
5	-	-	0.2	-	11.9	12
Apr. 8	-	-	0.8	-	8.7	10
10	-	-	0.7	-	16.2	17
44 hrs.						

() = Adjusted figure

* = 5 ppm ORG-N added when no K_j-N or ORG-N available

+ = Tucson Sewage Treatment Plant composite effluent

During the same period, PFE nitrogen quality has deteriorated somewhat so that a range of 6-17 ppm total nitrogen averages about 11 ppm (Table 16) as compared to 5.5 ppm for the previous operation of the same Bay. (Table 5).

6. FISH POND QUALITY

Table 17 is a summary of intermittent data on the quality of fish pond water at the overflow pipe from each pond and is self-explanatory. More information is available under the Sanitary Engineering and Fisheries sections of this report. Of interest to the future operations concerned with recreation lakes and a suitable product for recharge or incorporation into an existing source of water, is the apparent decline in the total amount of nitrate-nitrogen as PFE waters move from pond to pond. Detentions in these ponds, depending on the mode (phase) of operation, are between 10 and 20 days. Suspect in this nitrate decline might be the living plant systems of the environment with nitrate utilizing root systems or direct utilization of nitrate by algal complexes within the ponds themselves.

7. DISCUSSION

It is evident, from the composite table covering the various types (phases) of operation, Table 18, that certain factors, physical as well as chemical, affect the quality of the end product (PFE). See also Figures 6 & 7 which are graphs representing the operational quality of the TWTP for the periods under consideration in this report, and quite vividly complement certain exceptions noted in project data of equivalent periods:

TABLE 16
NITROGEN CONSTITUENTS PFE
DISCONTINUOUS VERTICLE PUMPAGE
(BAY #3 OPERATION)

1967-68	NH ₃ -N	NO ₂ -N	NO ₃ -N	ORG-N	T-K ₁ -N	T-N
Dec. 18	-	-	4.3	-	4.8	9.1
1968						
Jan. 2	-	-	4.0	-	2.2	6
9	-	2.0	4.5	-	2.0	9
15	0.0	-	4.5	-	1.1	6
Mar. 28	-	0.3	5.0	-	7.0	12
29	-	0.3	5.0	-	5.9	11
Apr. 1	-	3.8	7.0	-	7.5	18
2	-	0.2	4.0	-	7.0	11
3	-	-	3.8	-	12.9	17
4	-	-	3.5	-	6.7	10
5	-	-	3.8	-	8.9	13
8	-	-	3.8	-	8.9	13
10	-	-	5.0	-	6.7	12

() = Adjusted figure

* = 5 ppm ORG-N added when no K₁-N or ORG-N available

+ = Tucson Sewage Treatment Plant composite effluent

TABLE 17
TUCSON WASTEWATER RECLAMATION PROJECT
JUNE 1967 - MARCH 1968
FISH PONDS RECEIVING PFE (PPMS-4 RUNS)

PHASE	POND	FLOW	pH	CO ₃ (CaCO ₃)	HCO ₃	NH ₃ -N	NO ₃ -N	K ₁ -N	PO ₄	B.O.D.	C.O.D.
<u>III</u>	A	↑	9.3	50	310	0.7	0.2	6.0	4	8.4	64
	B	↑	8.8	22	280	1.1	0.8	4.0	6.4	7.9	50
	C	↓	8.5	20	260	0.3	4.1	3.0	8	5.1	47
	D	↓	9.2	60	300	0.0	2.2	2.9	5	4.9	58
<u>IV</u>	A	↑	9.3	80	200	-	1.2	8.7	5	-	67
	B	↑	9.1	60	220	-	4.5	4.7	5	-	59
	C	↓	8.8	25	280	-	6.0	7.5	6	-	54
	D	↓	8.9	35	270	-	2.5	3.1	5	-	54

TABLE 18
TUCSON WASTEWATER RECLAMATION PROJECT
JUNE 1966 - APRIL 1968
PHASED OPERATIONS
AVERAGE CONCENTRATIONS IN PPM

	PHASE I		PHASE II		PHASE III				PHASE IV		
	PFI ^a	PFE ^b	PFI	PFE	PFI	SURF ^c	PFEV ^d	PFE	PFI	SURF ^c	PFE
NH ₃ -N	29	< 0.2	23	0.4	17	5	6.6	0.8	20	*	-
NO ₃ -N	0.4	3.1	0.1	2.6	0.2	0.2	0.3	4.0	0.2	0-2.0	4.9
Kj-N	32	1.9	28	2.8	23	13	7.8	5.5	27	9-25	6.8
Total-N ⁺	32.4	5.0	28.1	5.4	23.2	13.2	8.1	9.5	27.2	(9-27)	11.7
D. O.	(1-3)	(3-6)	(2-4)	(4-8)	(2-4)	(10-30)	≤ 0.5	(5-9)	(1-3)	(5-40)	(6-10)
B. O. D.	(15)	(1.3)	12	1.8	13	-	4.4	5.7	27		9.4
C. O. D.	(65)	(13)	68	21	68	57	25	18	105		25

a = Pilot Filter Influent (Secondary Activated Sludge)

b = Pilot Filter Effluent (Horizontal Component)

c = Surf (Surface PFI After 20 Hrs.)

d = PFEV (Vertical Pumpage Only)

* = Surface Removals Began April 2, 1968, therefore, Ranges only

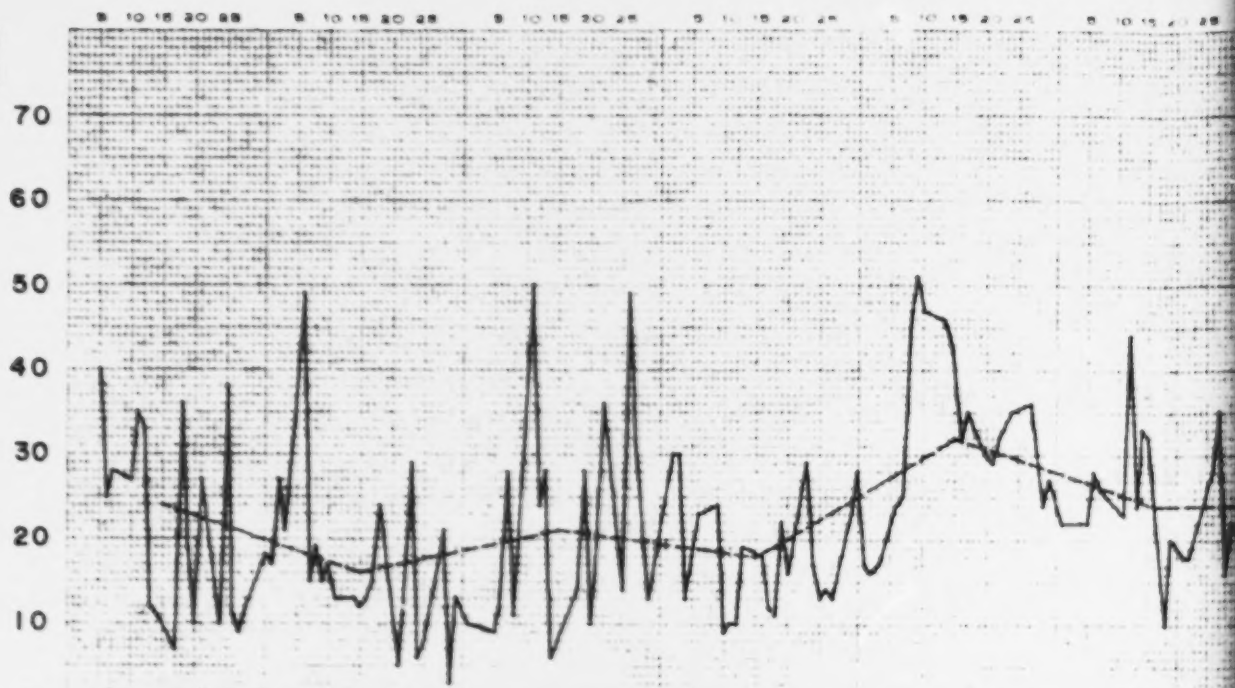
+ = Total Kjeldahl Plus Nitrate Nitrogen (No Nitrite-N)

() = Adjusted Values

TUCSON SEWAGE

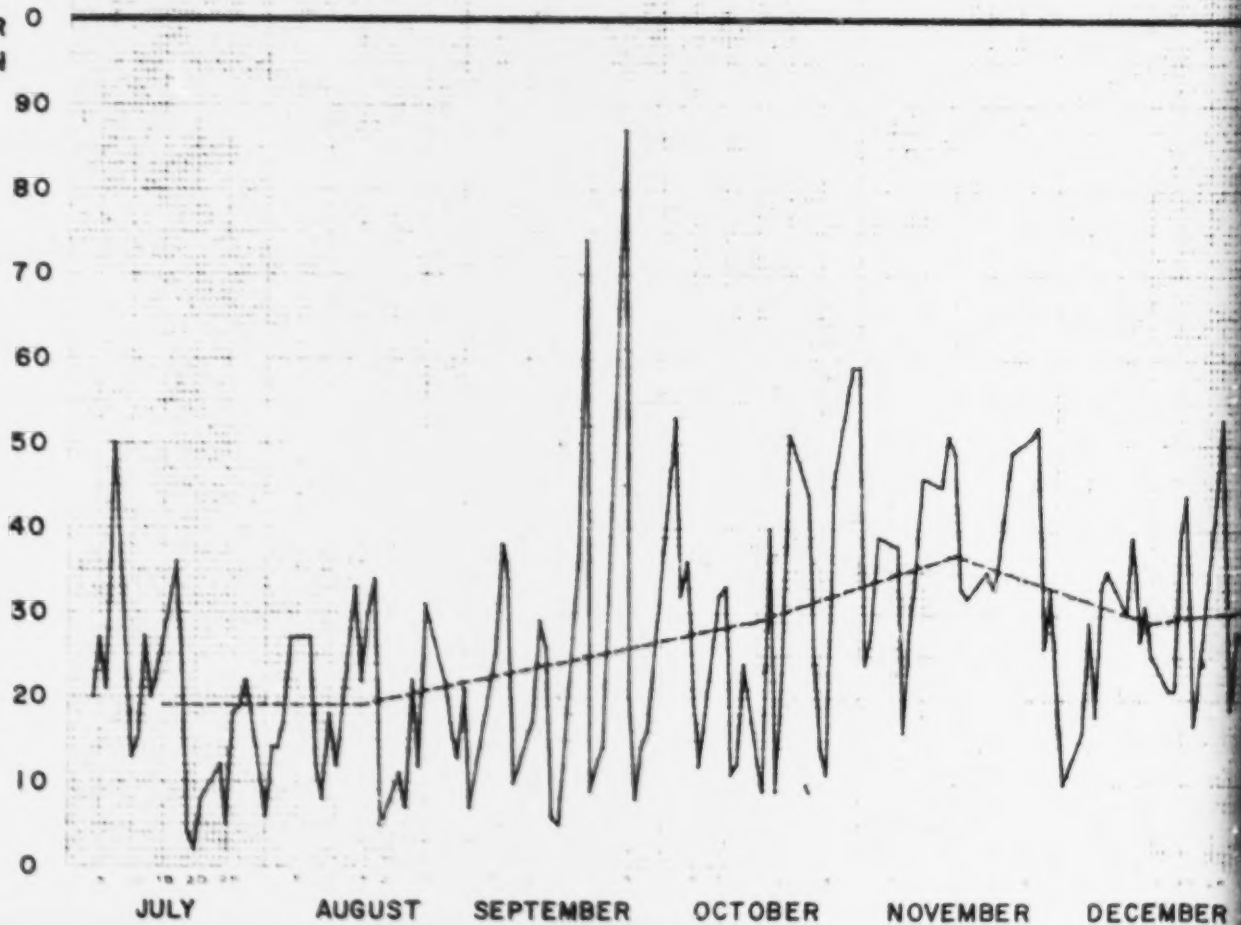
PARTS PER
MILLION

FUSING DIETZGEN CO.
MADE IN U.S.A.



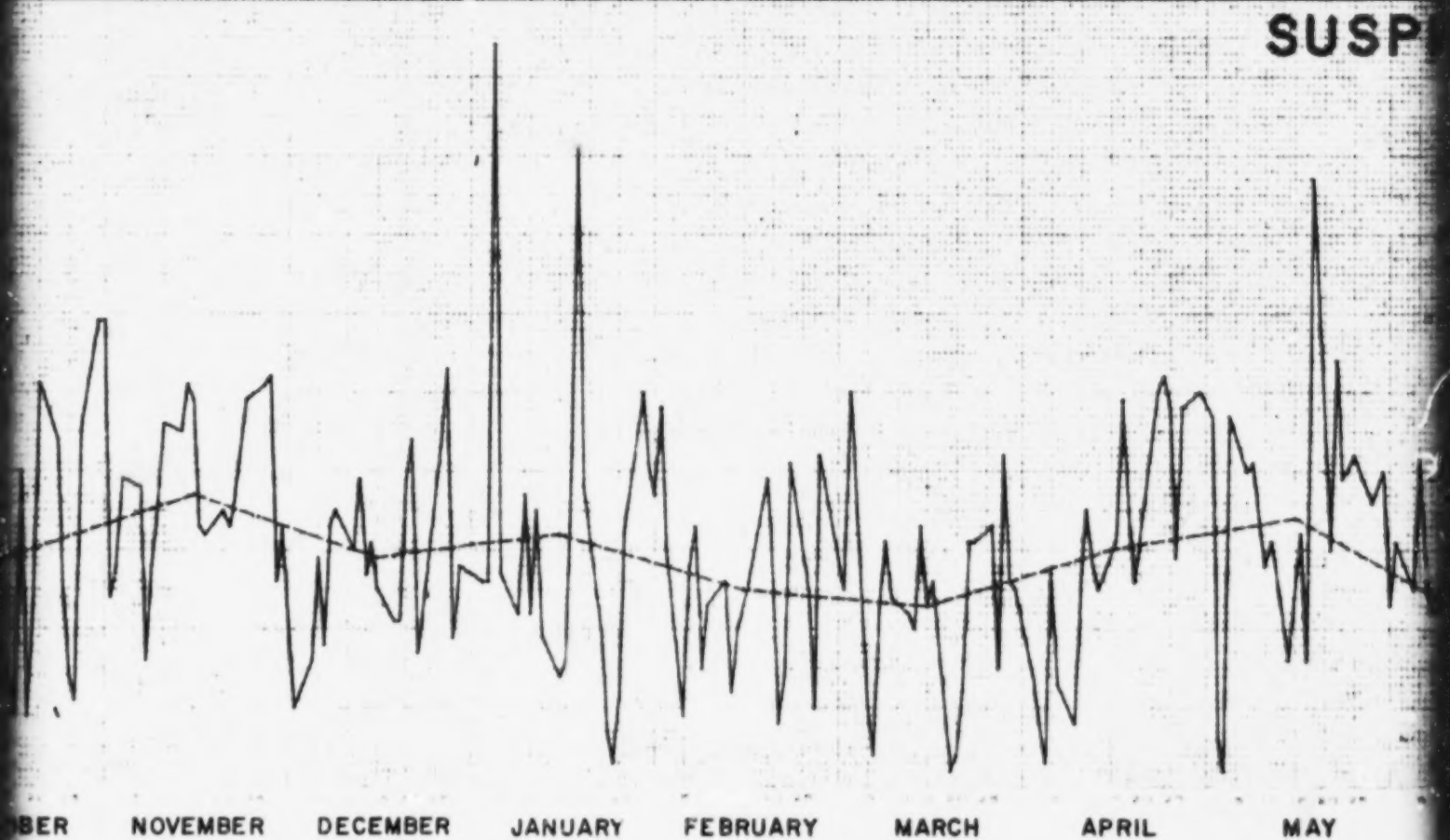
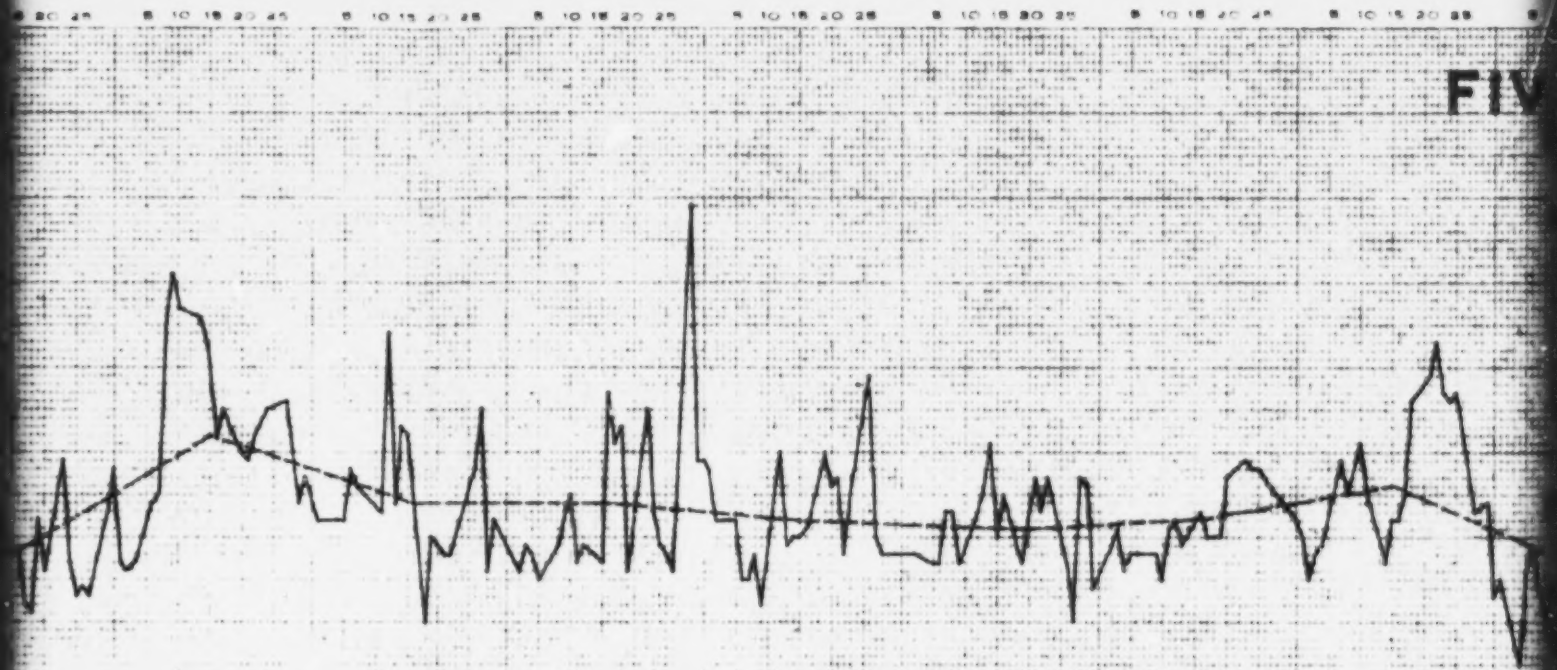
PARTS PER
MILLION

NO. 3410-T-18 DIETZGEN GRAPH PAPER
YEAR BY DAYS



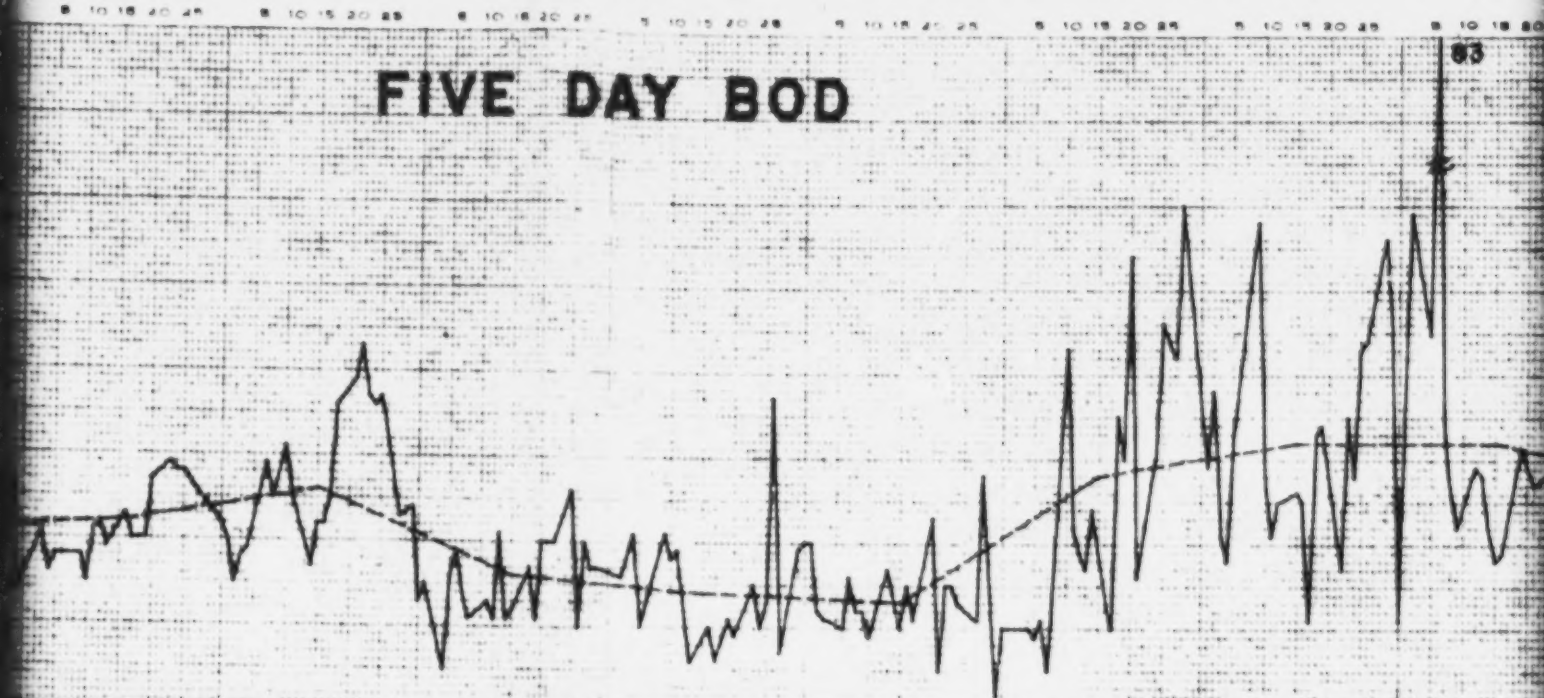
1966

ON SEWAGE TREATMENT PLANT -ACT

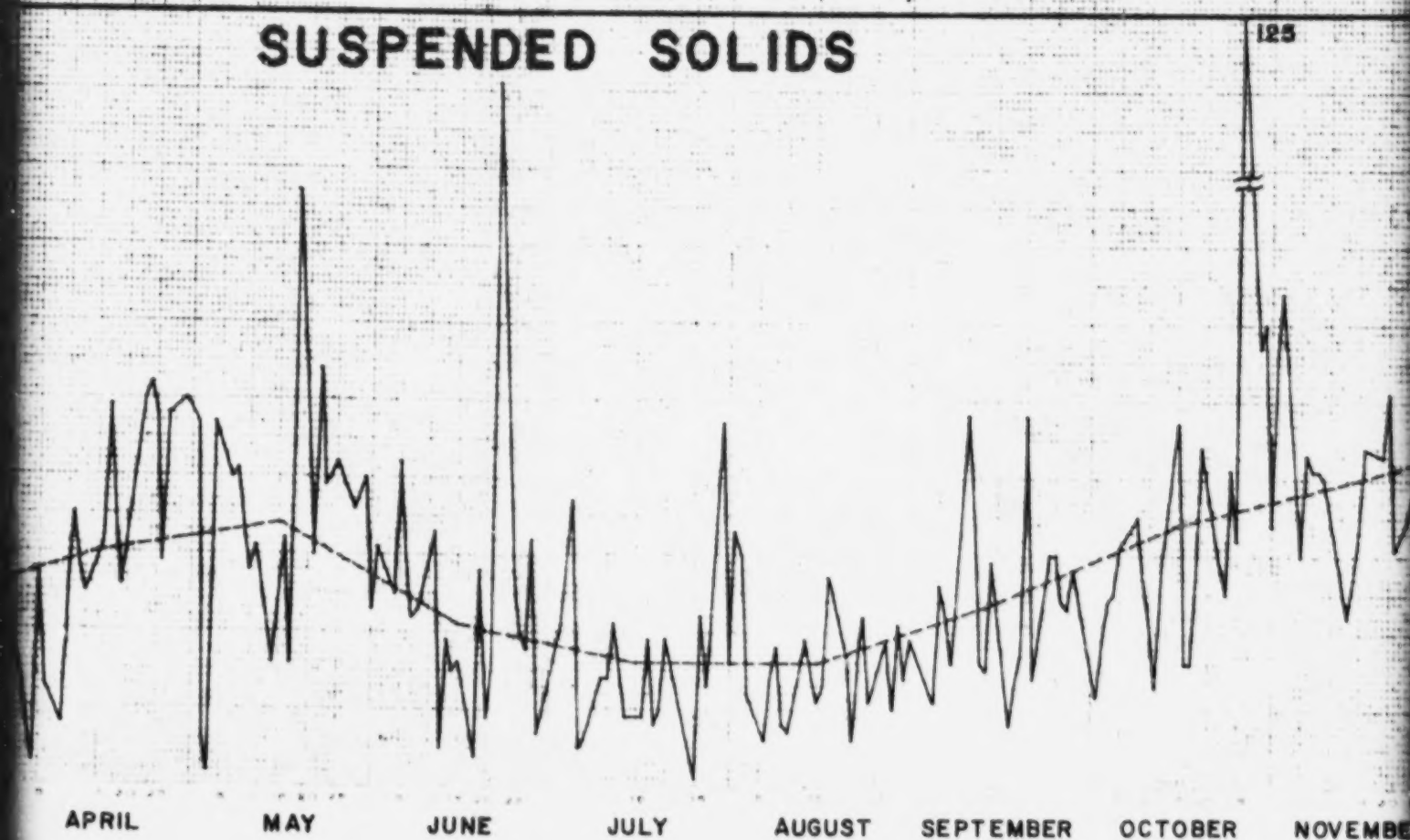


PLANT -ACTIVATED SLUDGE NO.1 - FIN

FIVE DAY BOD



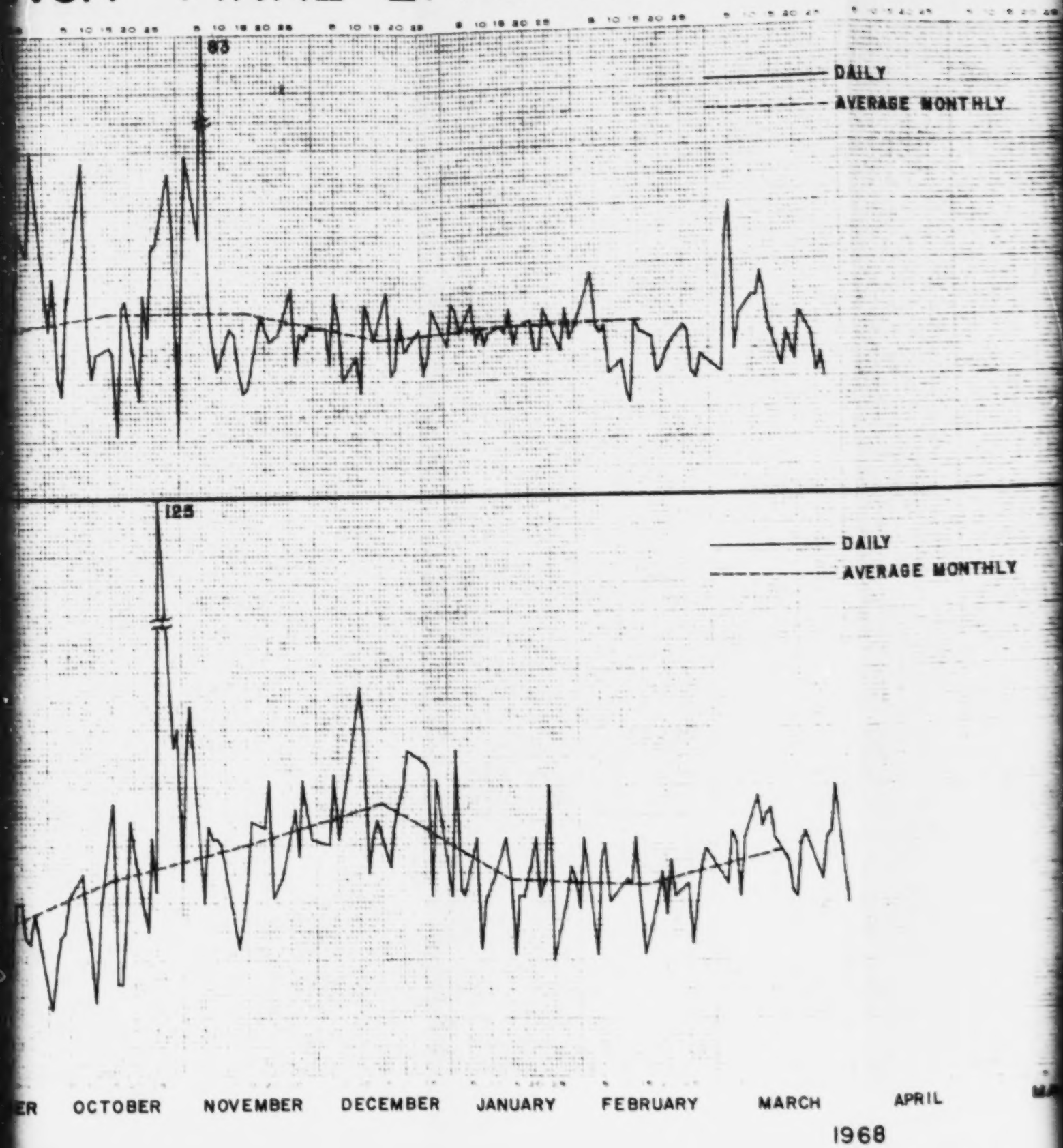
SUSPENDED SOLIDS



APRIL MAY JUNE JULY AUGUST SEPTEMBER OCTOBER NOVEMBER

1967

NO. 1 - FINAL EFFLUENT



EFFLUENT

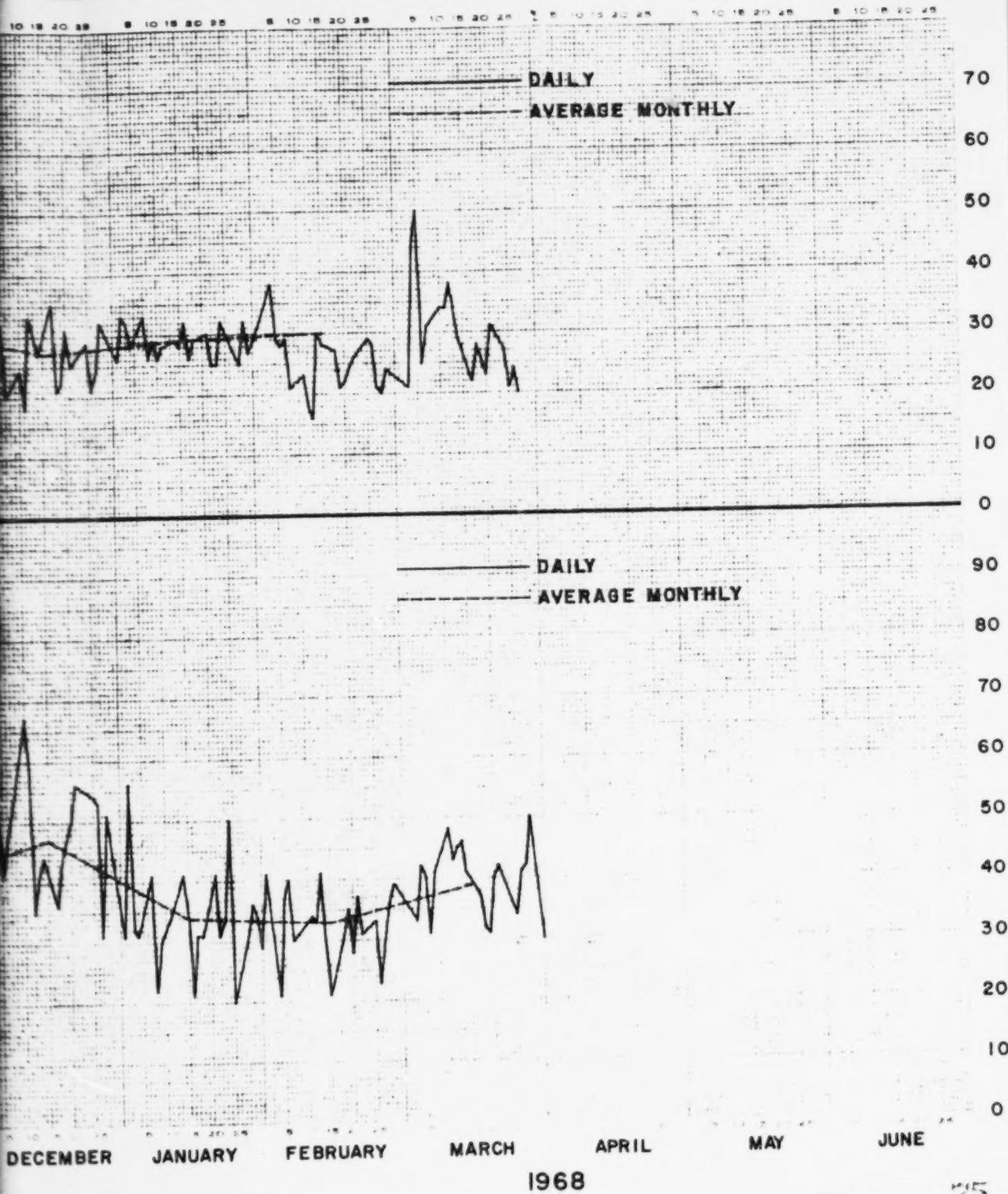
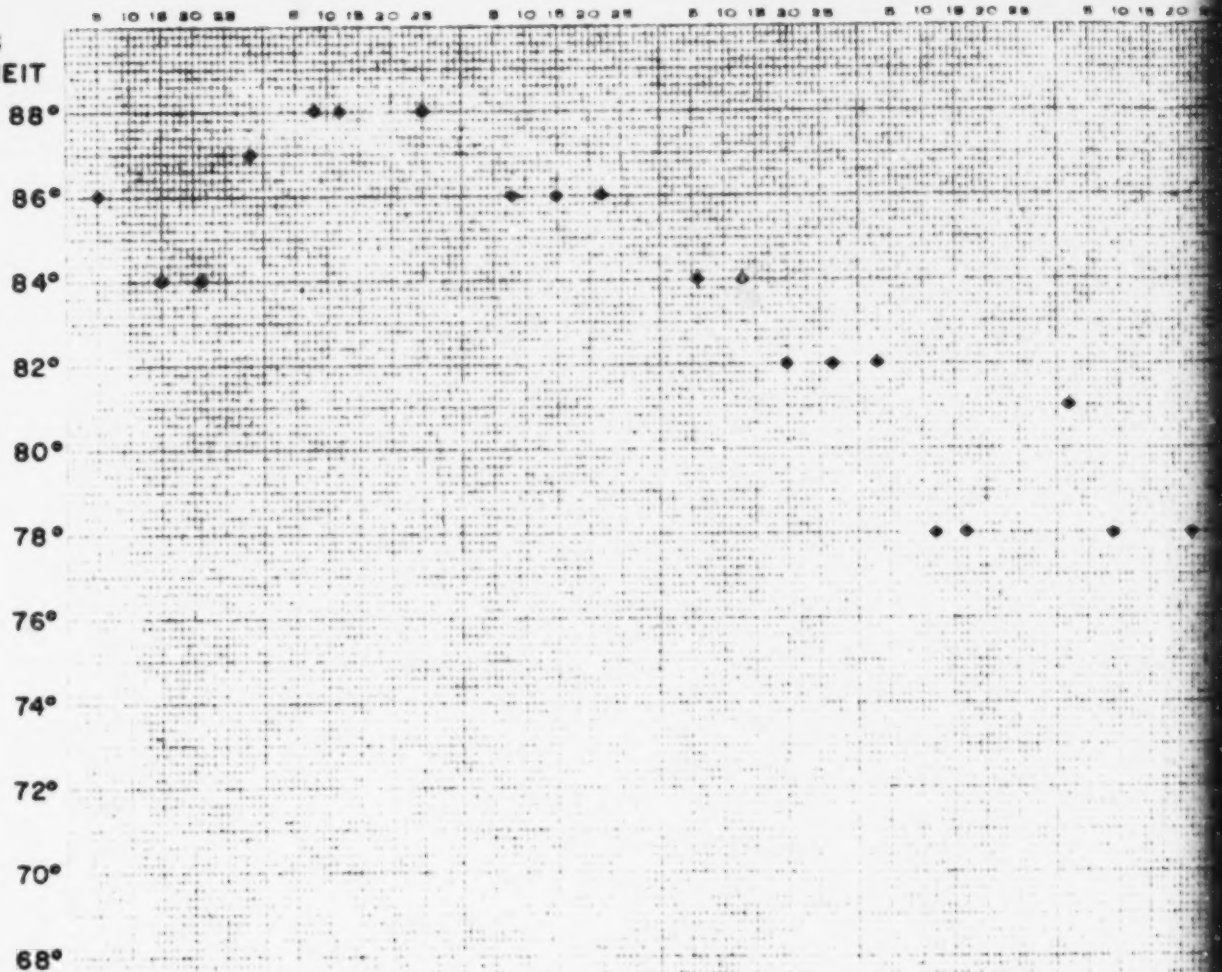


FIG. 6

TUCSON SEWAGE

DEGREES
FAHRENHEIT



PARTS PER
MILLION

5.0

4.0

3.0

2.0

1.0

0

JULY

AUGUST

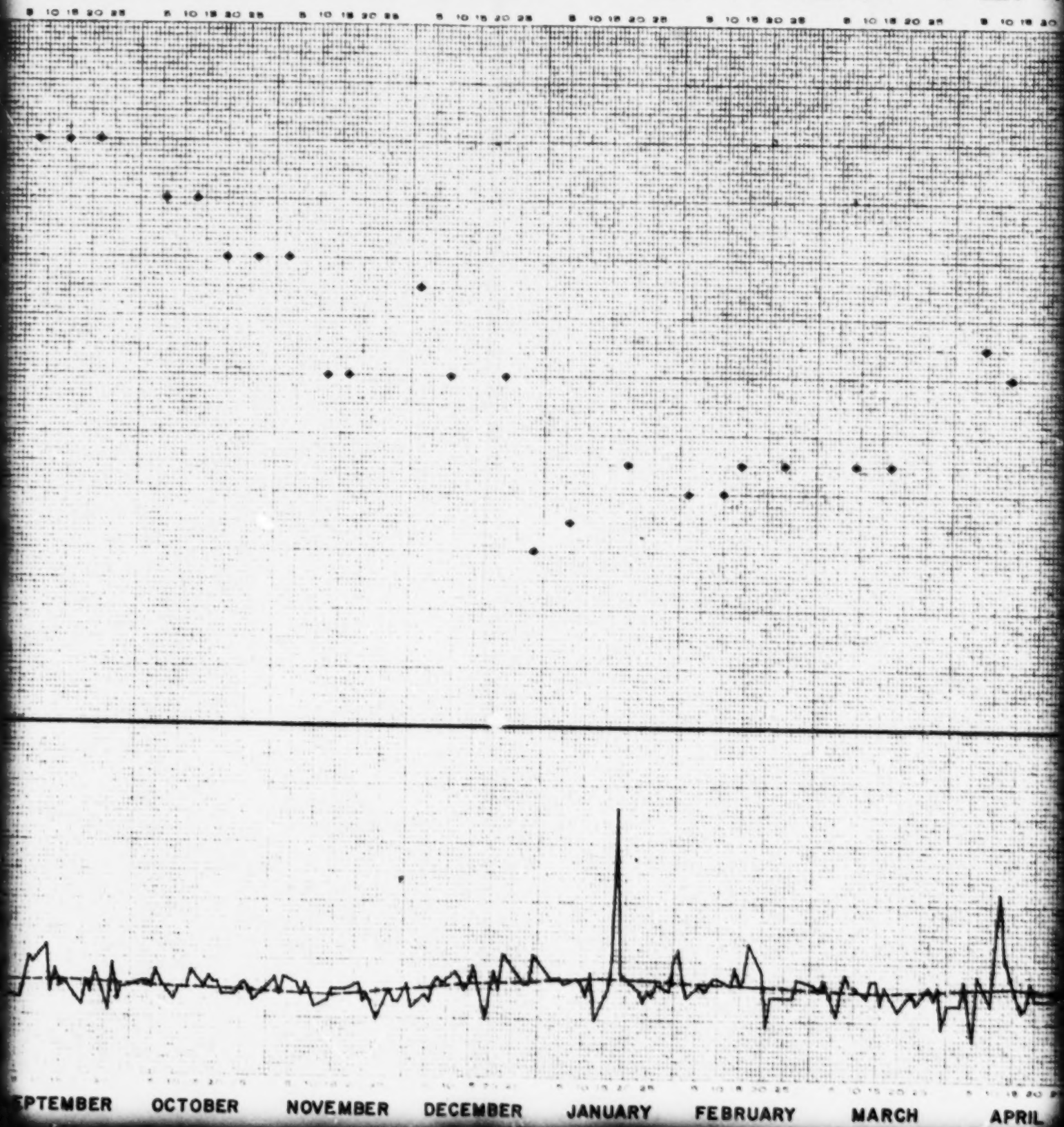
SEPTEMBER

OCTOBER

NOVEMBER

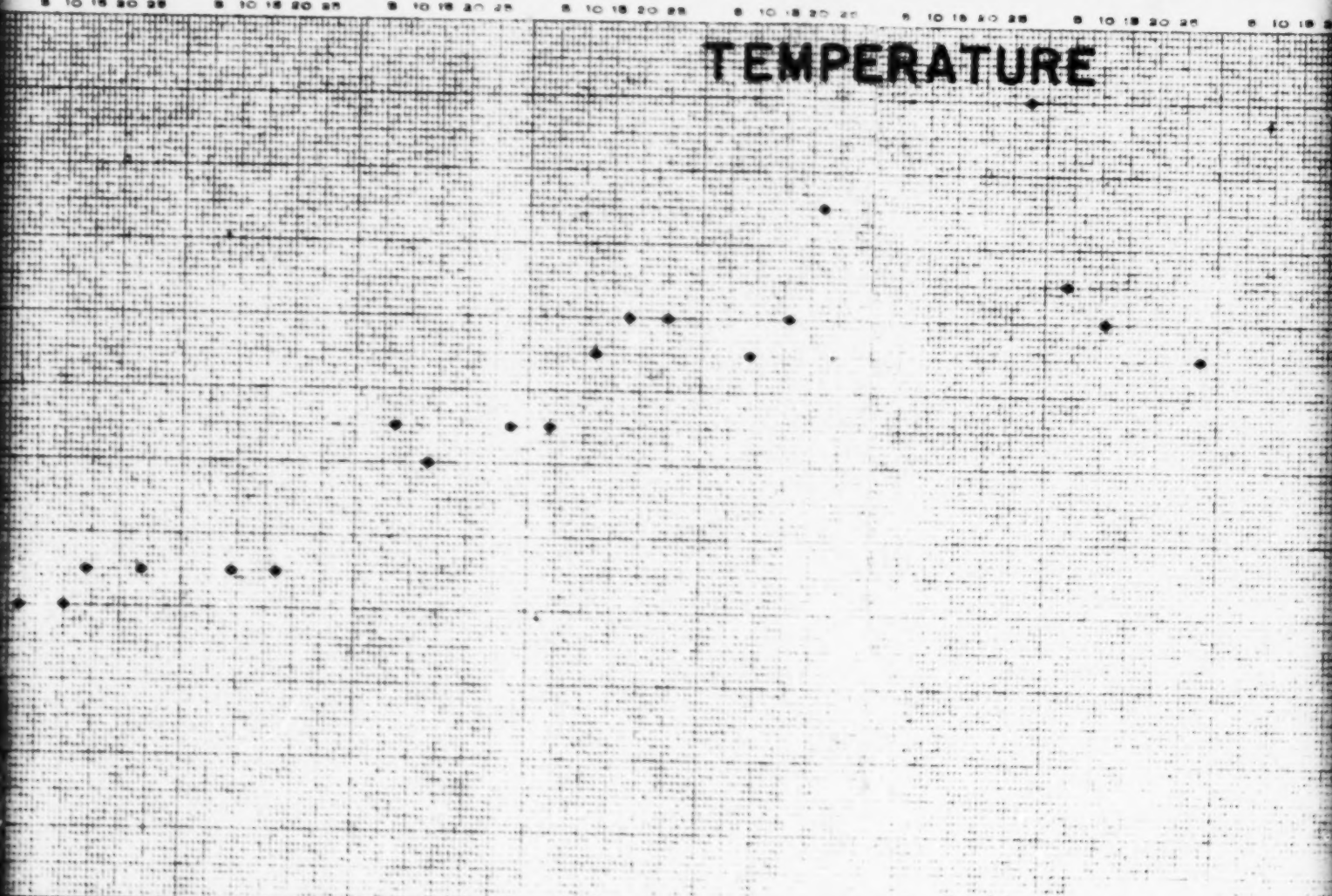
DECEMBER

TUCSON SEWAGE TREATMENT PLANT



WASTEWATER TREATMENT PLANT - ACTIVATED SLUDGE

TEMPERATURE



DISSOLVED OXYGEN



FEBRUARY

MARCH

APRIL

MAY

JUNE

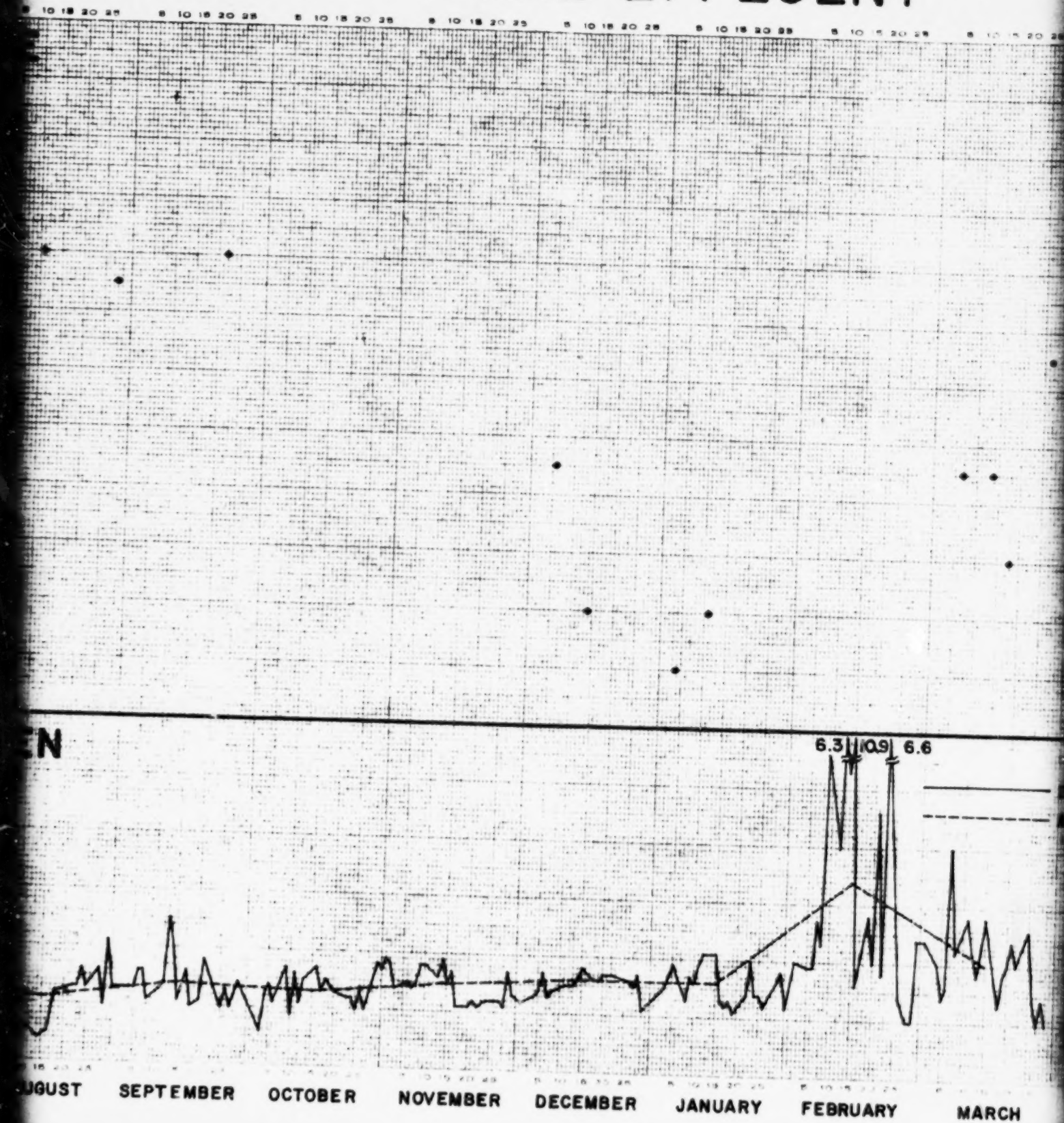
JULY

AUGUST

SEPTEMBER

1967

SLUDGE NO. 1 - FINAL EFFLUENT



L EFFLUENT

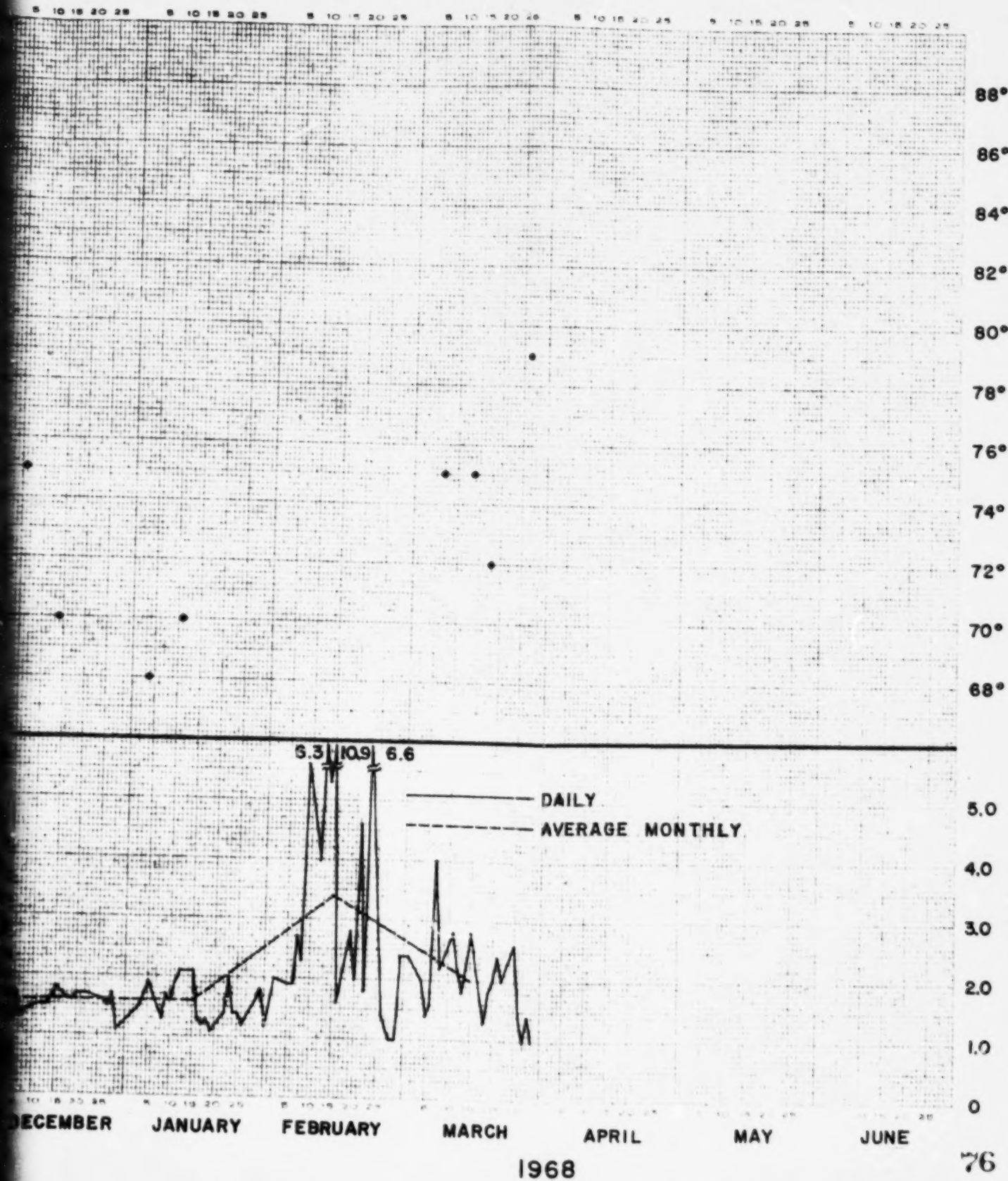


FIG. 7

- (1) Environmental temperature and light
(Seasonal variations)
- (2) Ammonia nitrogen
- (3) Nitrate nitrogen
- (4) Filter media saturation
- (5) Suspended solids

In the future consideration of a production filter activity, much thought and planning should be given to methods of detention of the source water to any filter operation, and especially to the utilization of the natural phenomenon which occurs between April and November of any calendar year. Future analytical studies on the chemistry of the filter should include gas analyses, pesticide removals, and metabolite identification for any research explanation of the biochemical mechanisms involved are yet to be answered. It would be specifically interesting to know, (a) quantitative analyses of the gases evolved from the waters dormant on the filter surface; (b) the concentration of pesticides and their metabolites in activated sludge effluent and PFE; (c) the nature and identification of the higher molecular weight amino acids, organic acids, and the modification of their forms in the passage thru the Pilot Filter; and (d) the phenomenon responsible for oxygen depletion and nitrate utilization in the pond systems.

Ammonia nitrogen should be carefully observed in any future operation of fish pond systems, not alone for its B.O.D. quality, but because of the toxicity to certain aquatic life.

Nitrate began its history with the project as an undesirable entity, but it is our feeling at this moment that the recreational lake system with its natural vegetation fed from a tertiary treatment facility, will quite adequately treat the nitrate concentration to a point that the ground water systems, and even direct water system incorporation after chlorination, will not suffer from unreasonable amounts of this ion.

From time to time unsaturated areas of the Pilot Filter media were inundated with large quantities of Pilot Filter influent and the resultant production of noxious quantities of NO_3 were measured within the anaerobic filter environment, sometimes exceeding 100 ppm, which result suggested 100% conversion of influent ammonia nitrogen to nitrate. This would be a successful procedure for reducing a high B.O.D., but the overload would serve no desirable end since total nitrogen would not be reduced as, for example, is the case with the surface phenomenon and the vertical-horizontal travel effect.

The actual hydraulic operation of the filter has been hampered from time to time with arrival at the basin surfaces (PFI) of secondary activated sludge effluent high in suspended solids (SS). From a chemistry standpoint, this has not had a great effect, but since continued operation of an infiltration bay after such an undesirable slug of surface plugging material, the long range results would at least diminish the quantity, if not the quality, of water and at the same time probably abort the efficiency of surface removals.

8. RECOMMENDED LIMITS (CHEMISTRY)

A composite range of TWTP activated sludge effluent, PFE data (range), and recommended Limits of Quality is presented in Table 19. Those items taken into consideration in the preparation of these limits are:

1. Aesthetics
2. Toxicity
3. Available water source

TABLE 19
TUCSON WASTEWATER RECLAMATION PROJECT
APRIL 27, 1968
RANGE PPM

6/66 - 3/68

RANGE OF PPM	ASE (TWTP)	OBSERVED PFE	RECOMMENDED LIMITS
TDS	500-800	600-800	< 1000
SS	7-100	-	< 1.0
pH	7.5-8.0	7.2-8.2	< 9.0
B.O.D.	13-51	1-10	< 5.0
C.O.D.	50-105	13-25	< 25.0
NH ₃ -N	21-34	0.0-3.0	< 0.5
NO ₂ -N	0.005-0.02	0.01-3.0	< 0.5
NO ₃ -N	-	0.8-15	< 20.0
K _j -N	24-46	1-10	< 5.0
PO ₄	15-49	2-20	< 20.0

N

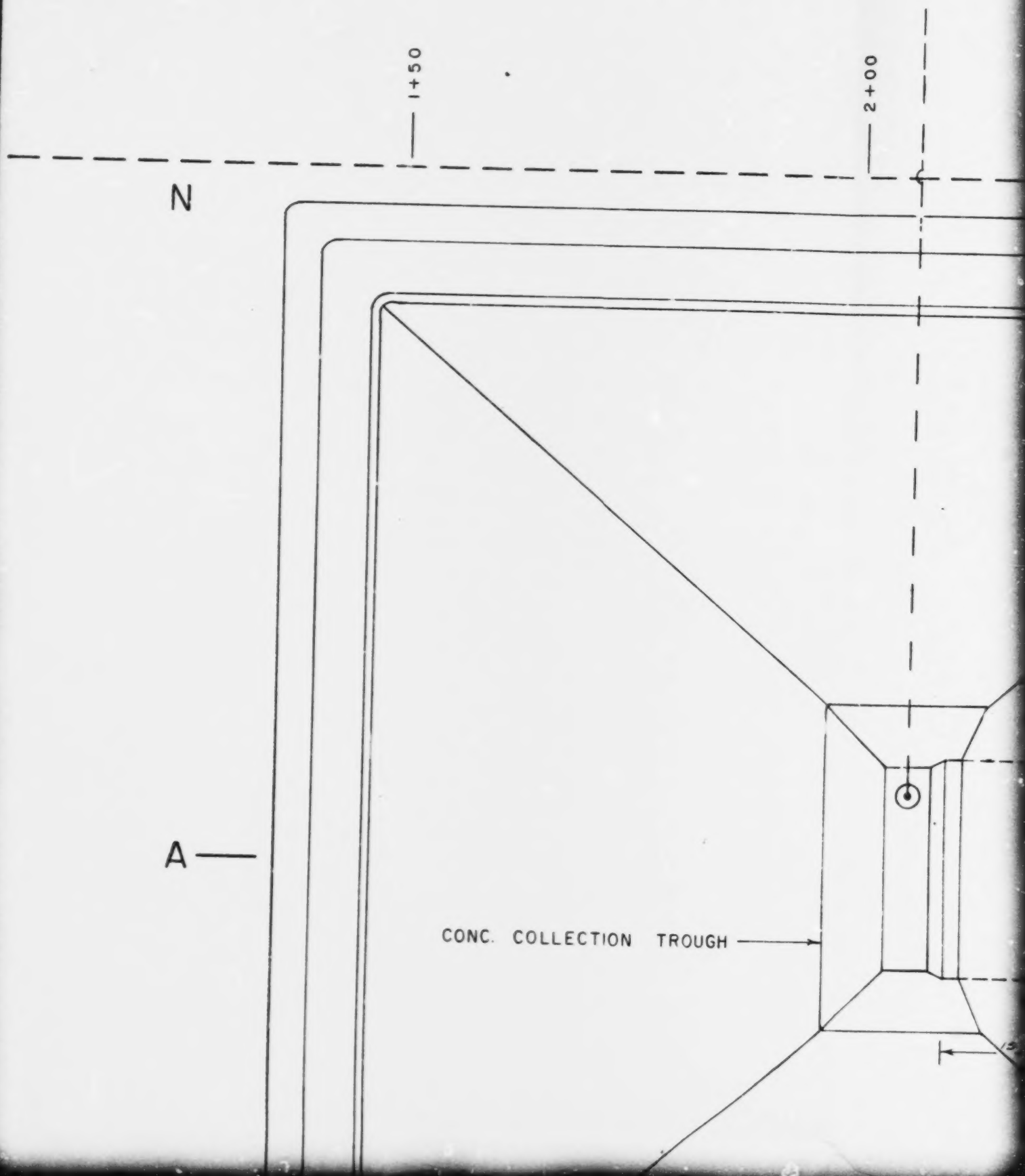
1+50

2+00

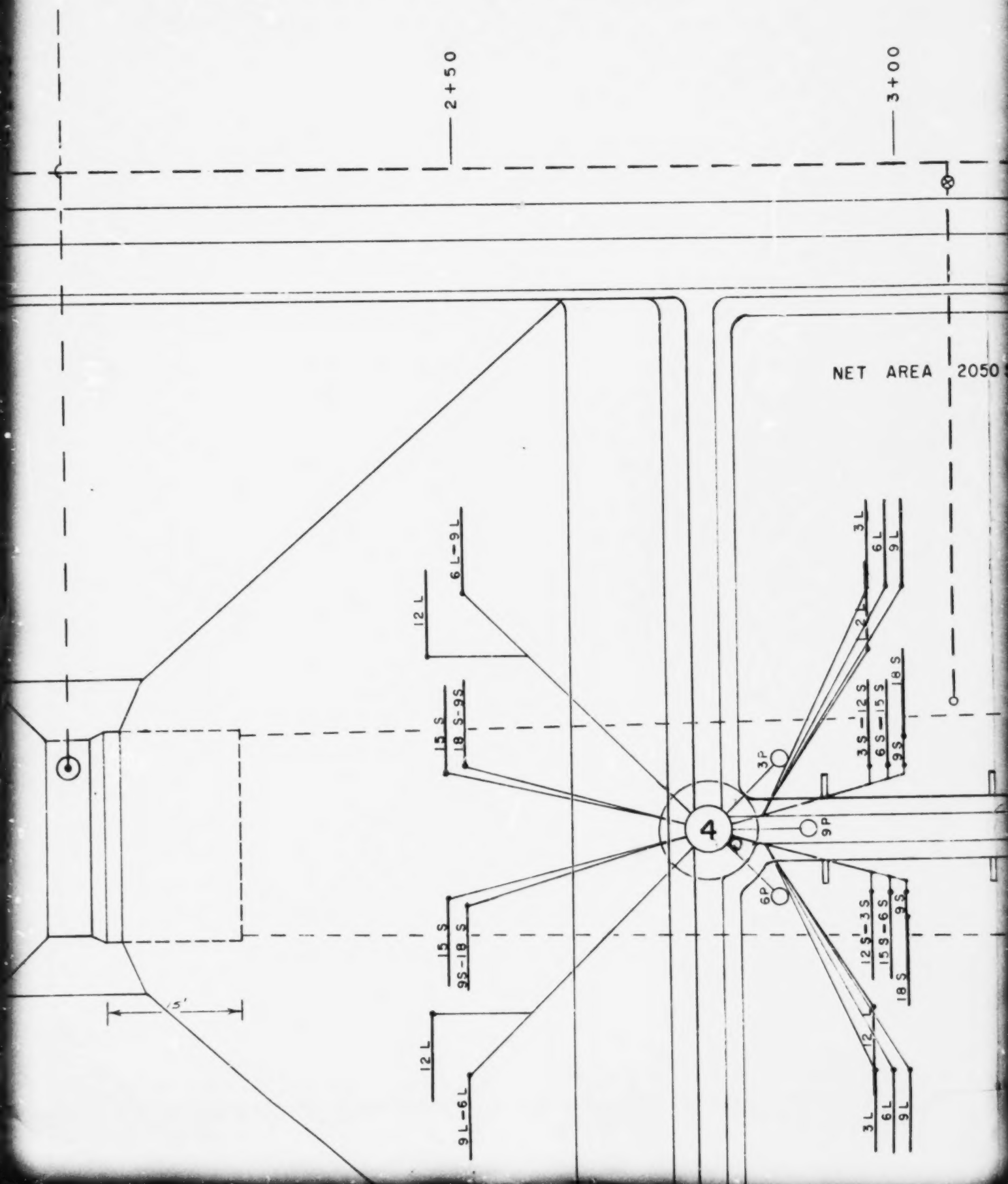
A—

CONC. COLLECTION TROUGH

1/2



B



C

3+00

3+50

NET AREA 2050 SQ. FT.

NET AREA 2320 SQ. FT.

NET AREA

3L
6L
9L
12L
15S
18S
3S-12S

12L
15S-6S
18S
9S
12S-3S

3L
6L
9L
12L
15S
18S
3S-12S

12L
15S-6S
18S
9S
12S-3S

3L
12L
15S
18S
3S-12S

12L
15S-6S
18S
9S
12S-3S

116'

116'

3P

9P

6P

3P

9P

6P

3P

9P

6P

W

W

C

D

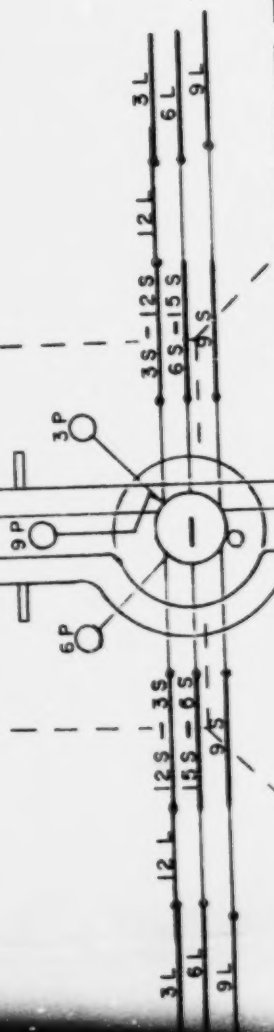
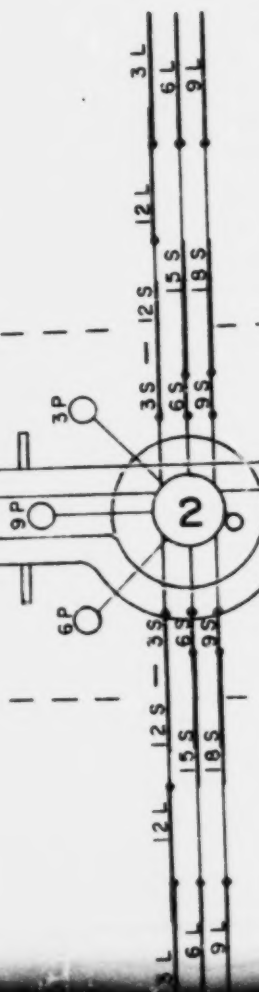
4+00

4+50

NET AREA 2320 SQ. FT.

NET AREA 3600 SQ. FT.

116'



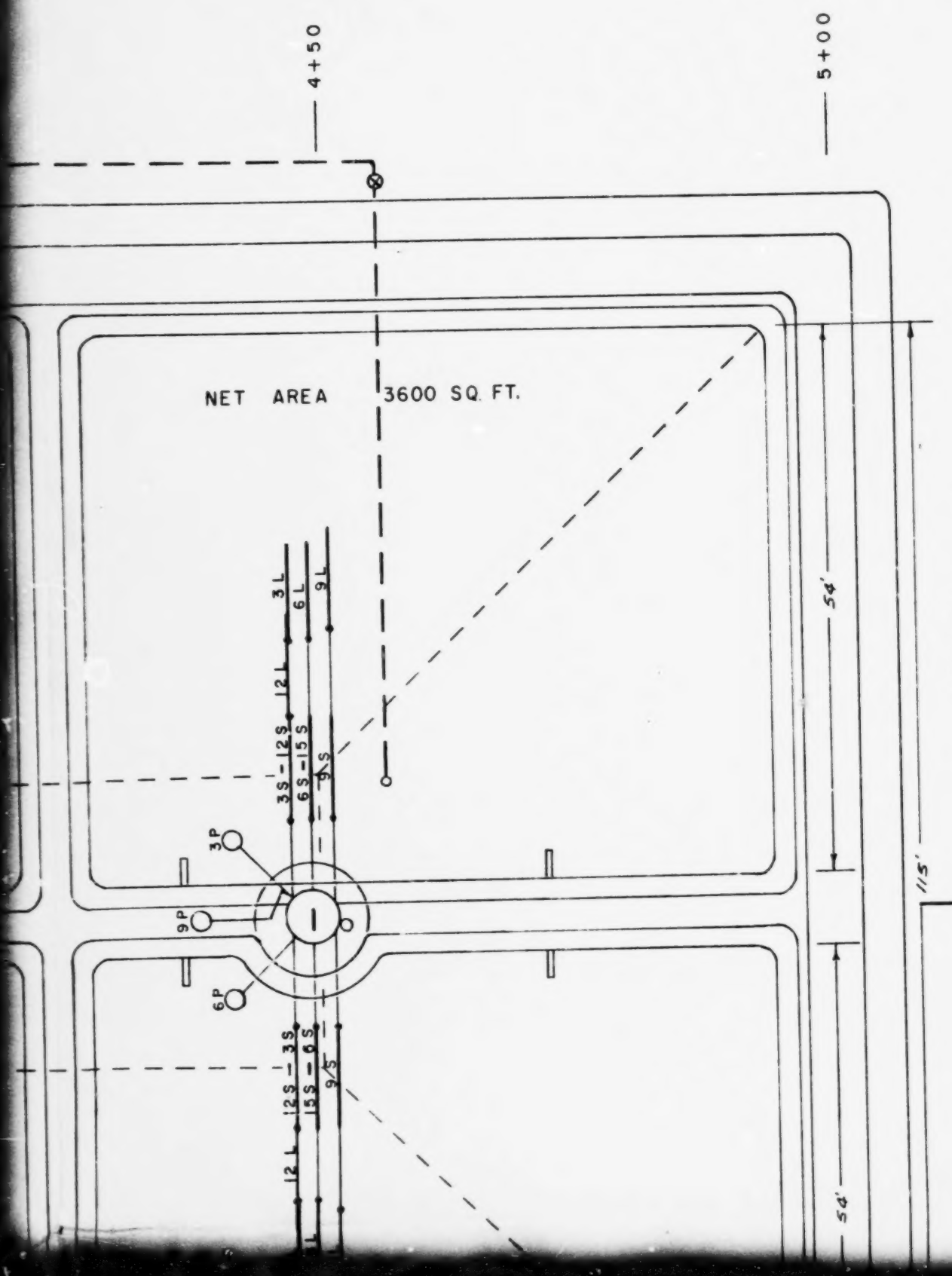
39

D

S

RECEIVED
NATIONAL TECHNICAL
INFORMATION SERVICE
JAN 15 1973

A'



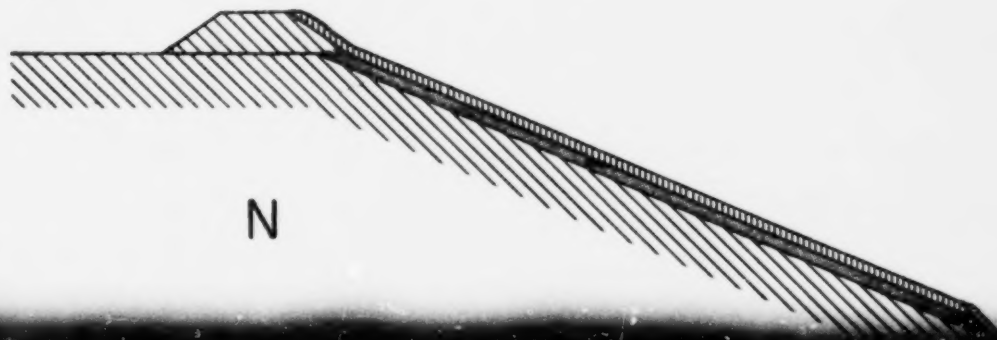
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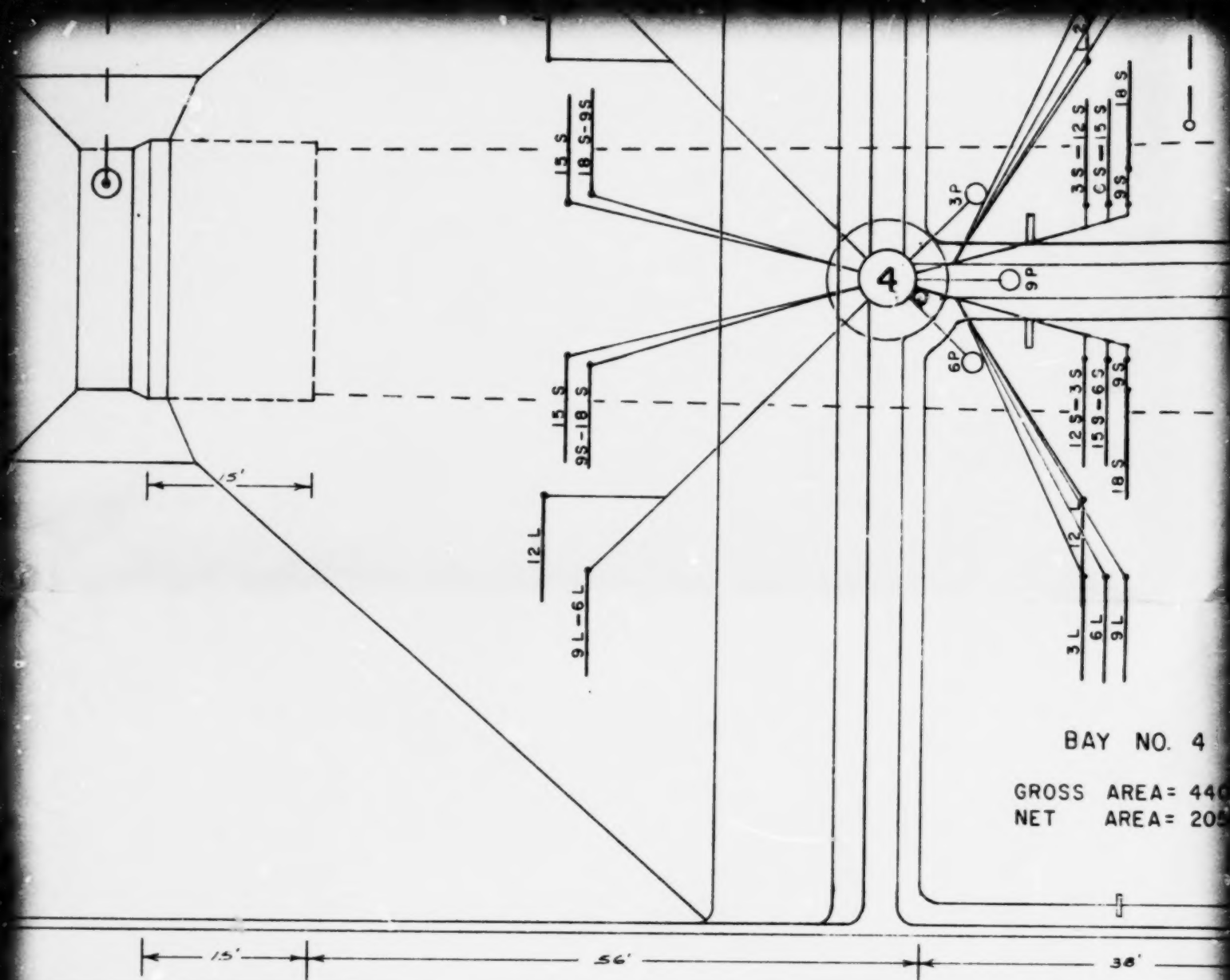
CONC. COLLECTION TROUGH

ELE. 2240 —

ELE. 2230 —

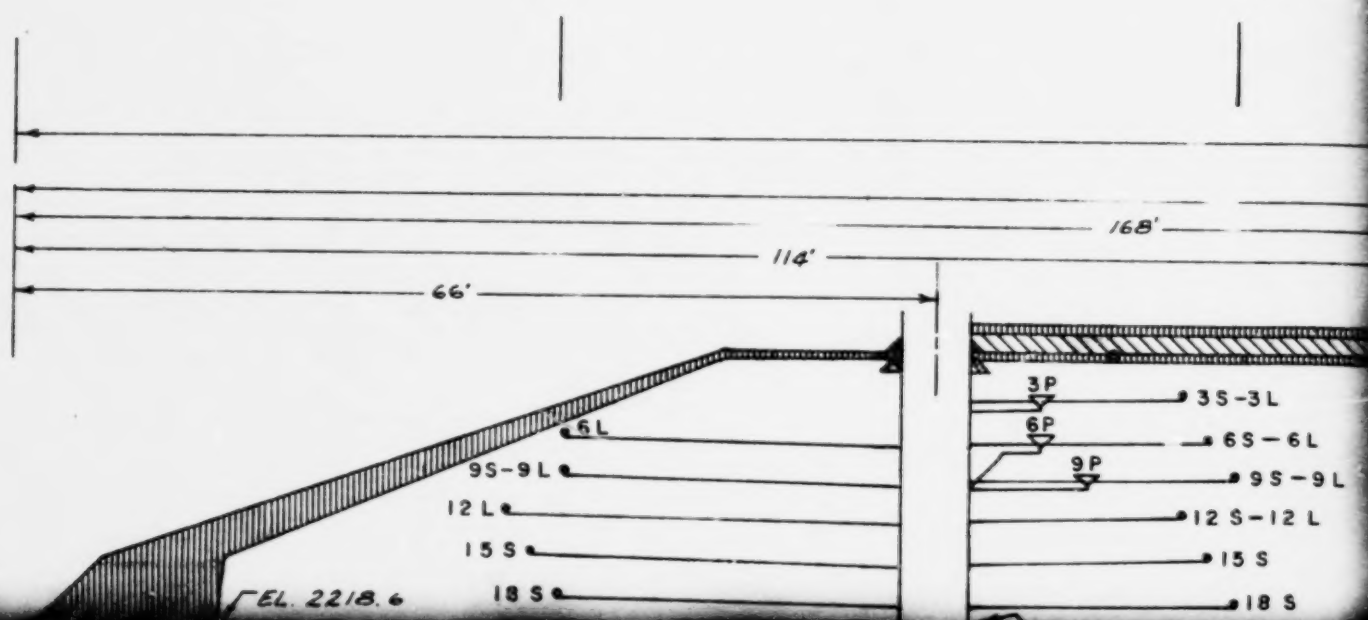
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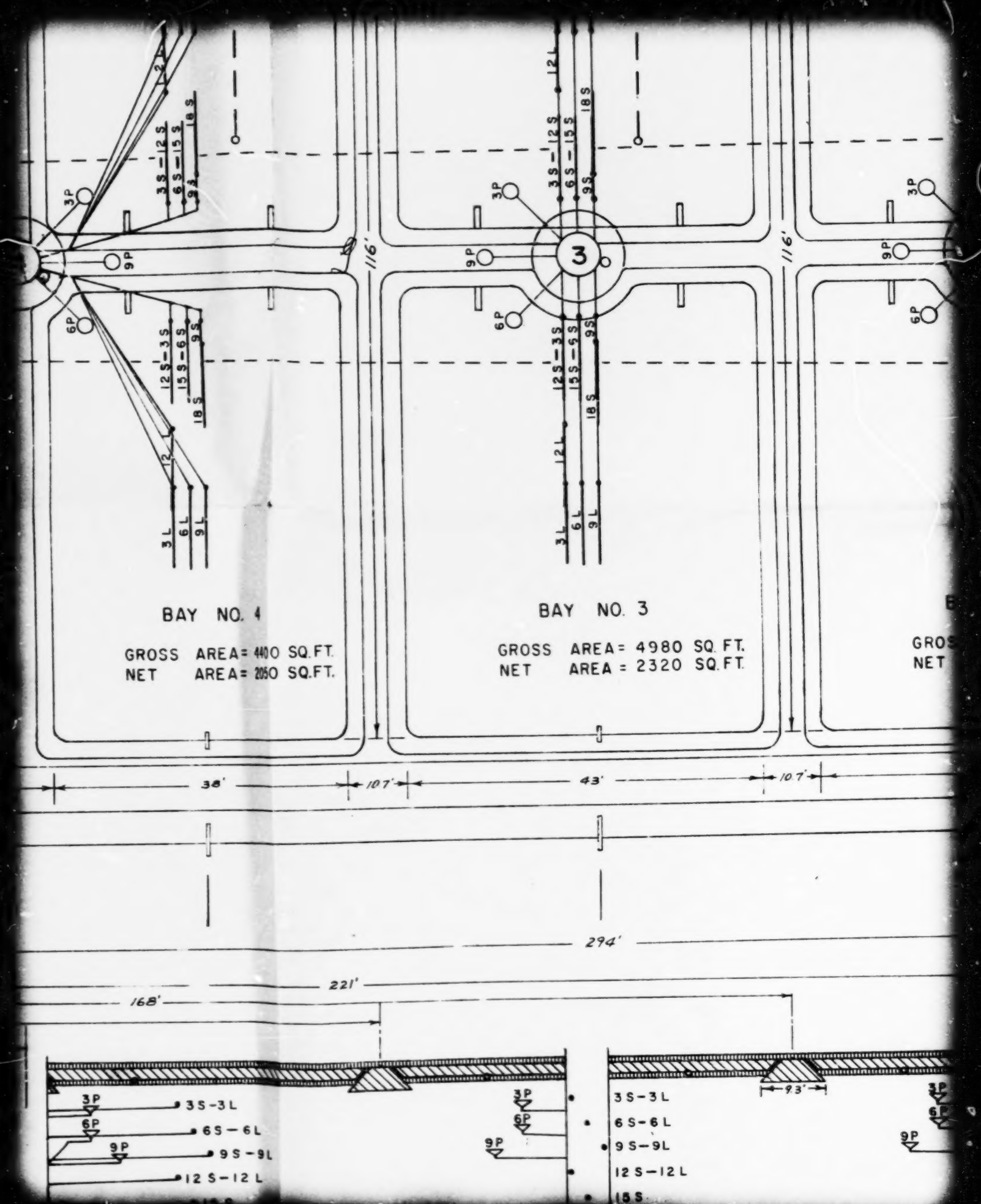


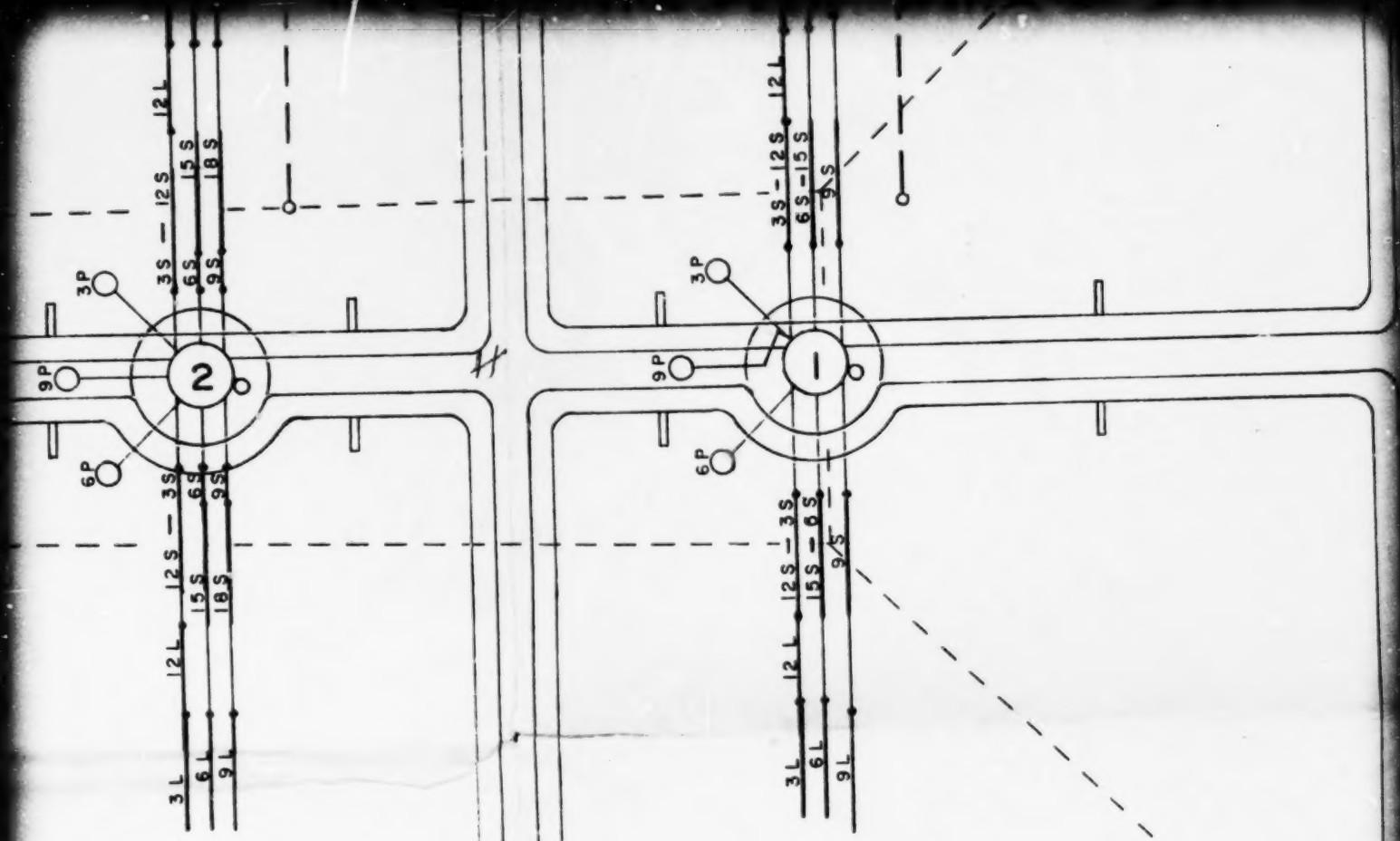
BAY NO. 4

GROSS AREA= 440
NET AREA= 205



EL. 2218.6





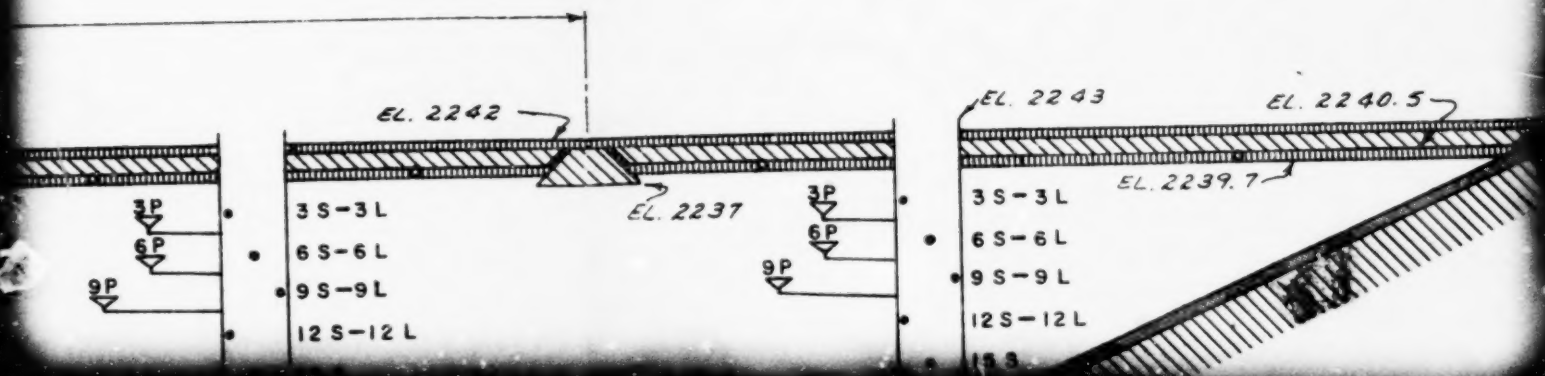
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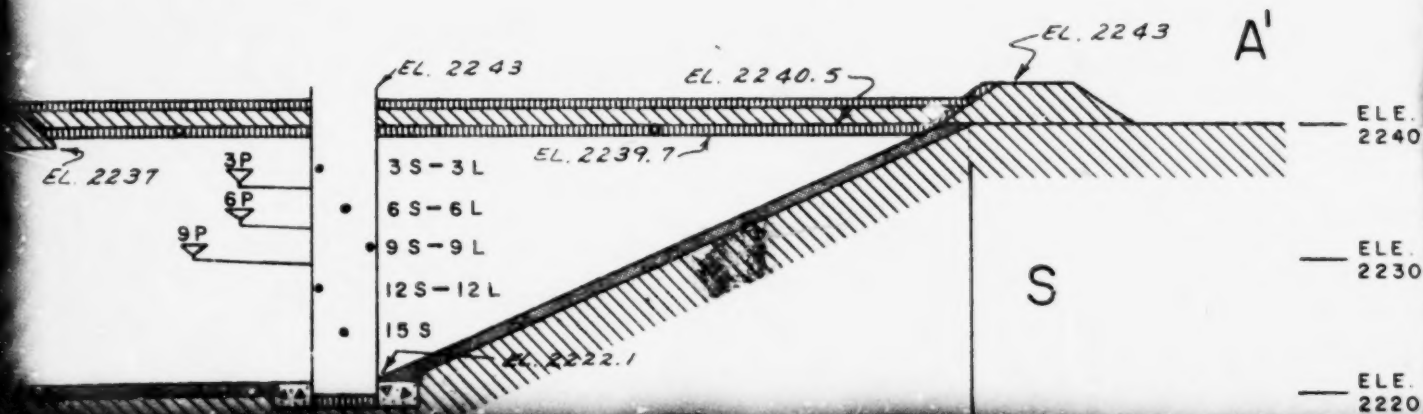
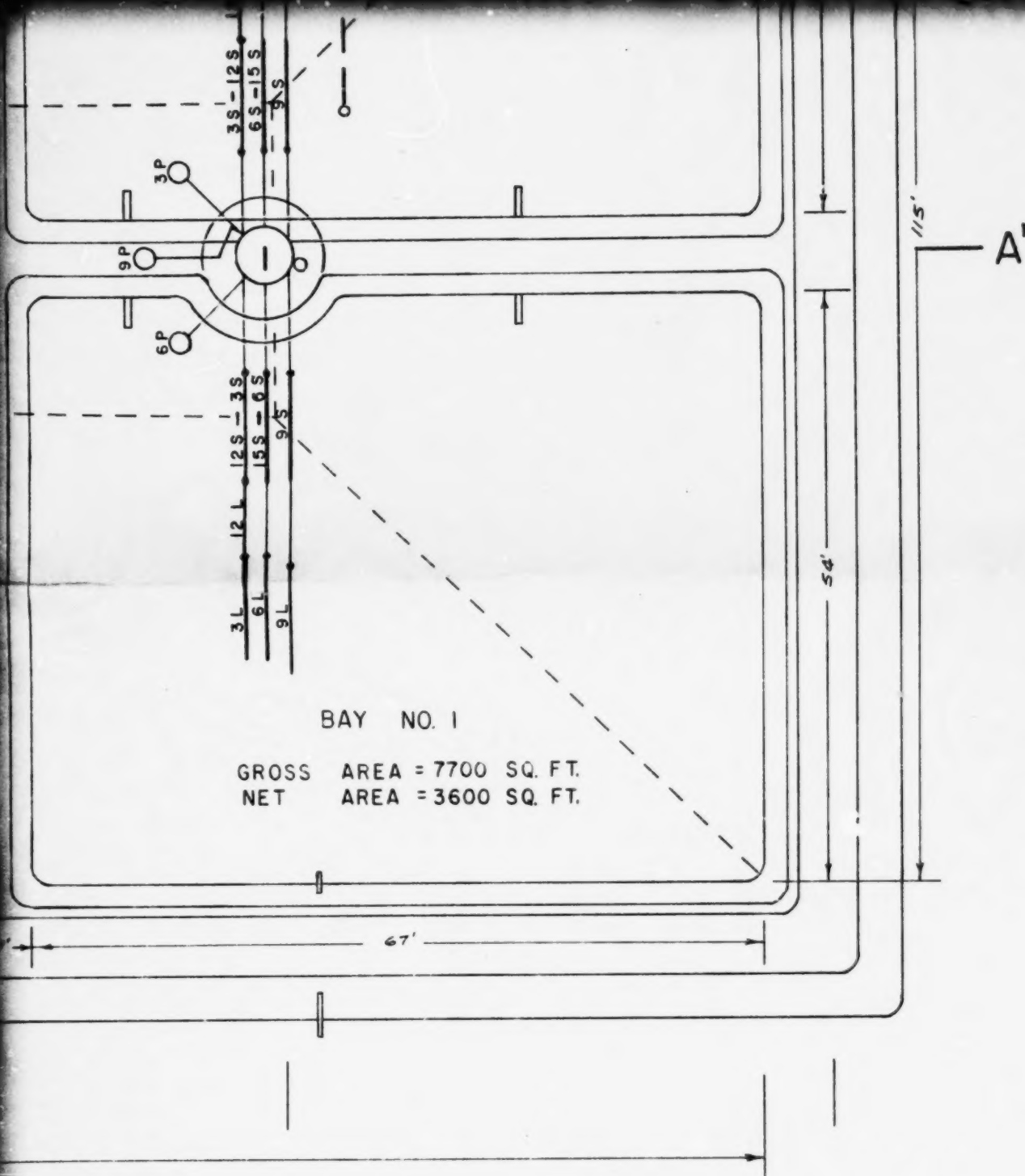
GROSS AREA = 4980 SQ. FT.
 NET AREA = 2320 SQ. FT.

BAY NO. 1

GROSS AREA = 7700 SQ. FT.
 NET AREA = 3600 SQ. FT.

43' 10.7' 67'





A
ELE. 2240 —

ELE. 2230 —

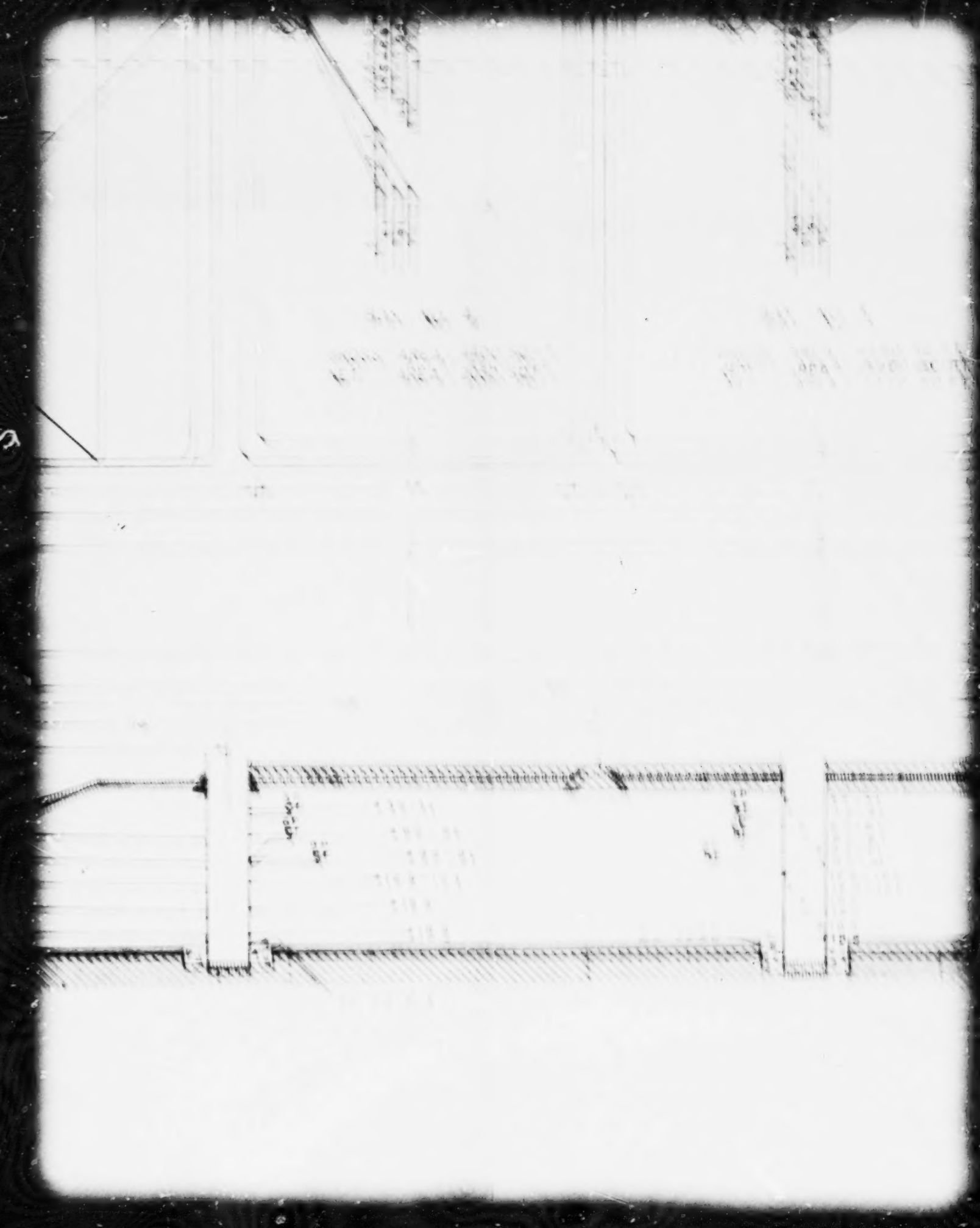
ELE. 2220 —

E. 2210 —

N

SITED

ER MEDIA



NO. 3

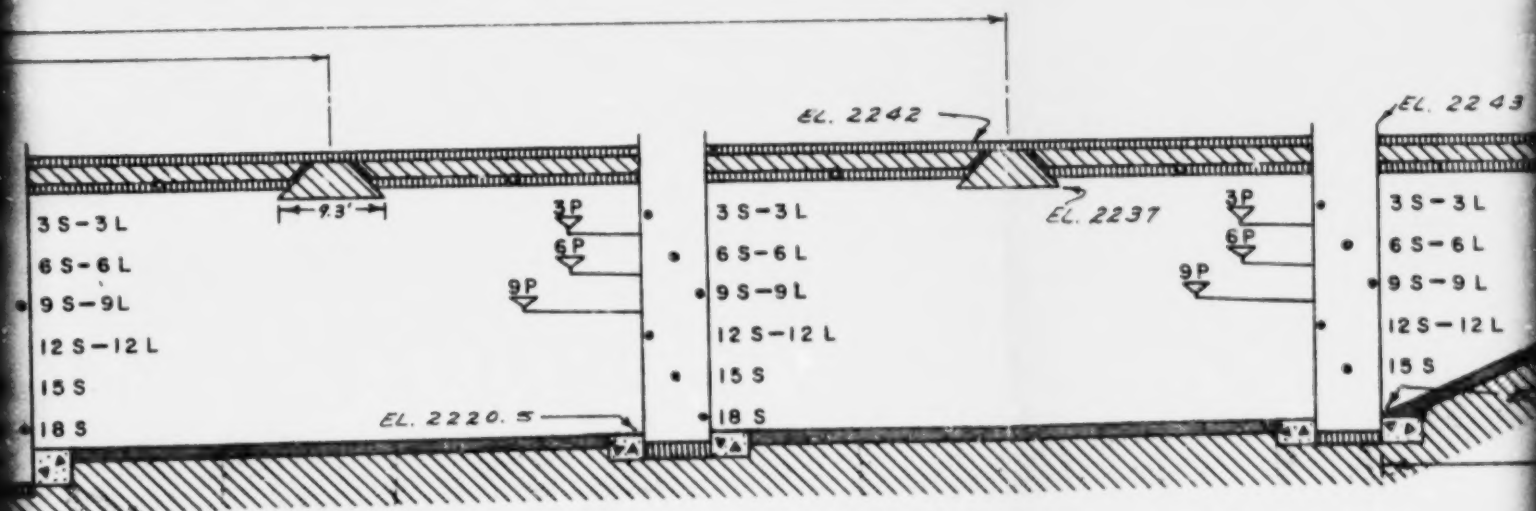
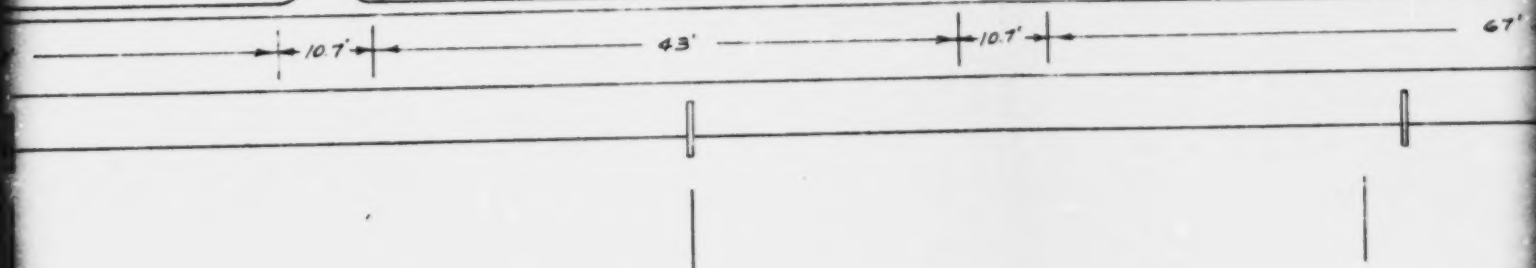
A = 4980 SQ. FT.
A = 2320 SQ. FT.

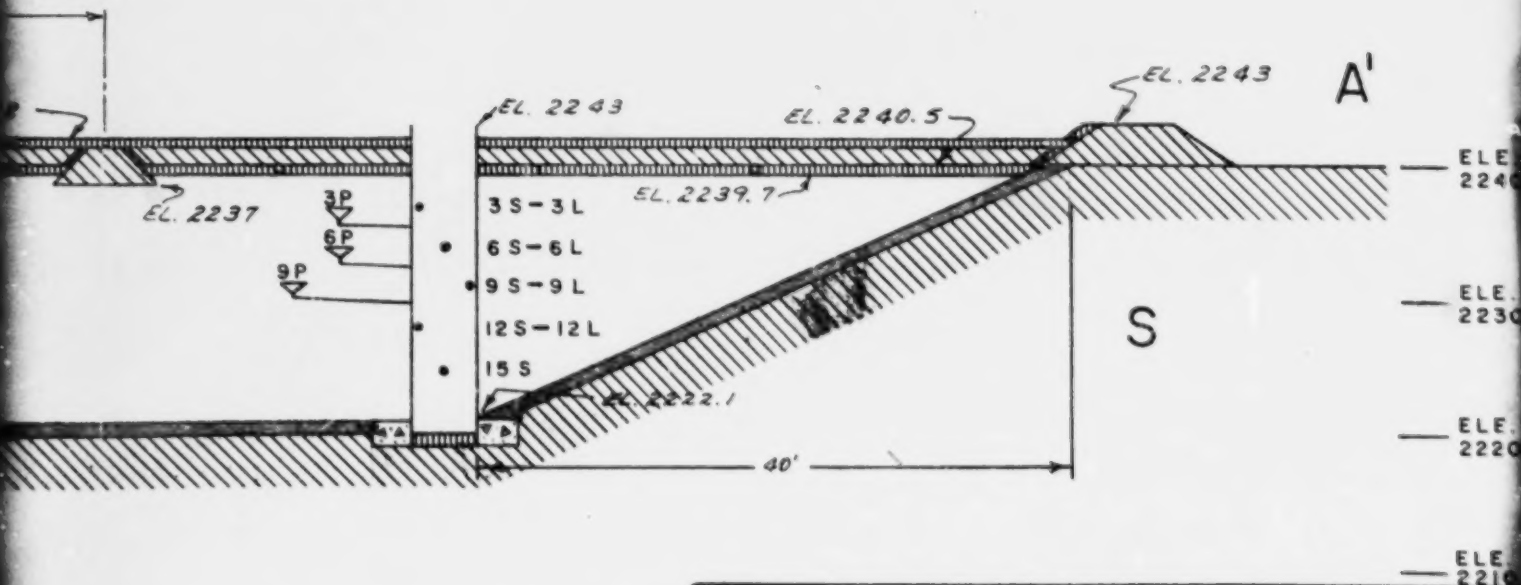
BAY NO. 2

GROSS AREA = 4980 SQ. FT.
NET AREA = 2320 SQ. FT.

BAY NO.

GROSS AREA =
NET AREA =





PILOT FILTER - AS BUILTS
PLAN AND ELEVATION A-A'

PLAN NO.

CHAPTER V
SANITARY MICROBIOLOGY

1. INTRODUCTION

This section summarizes to date the research activities and findings in Sanitary Microbiology during the past year. The results of testing of pilot filter for B.O.D., C.O.D., and bacteriological removals are presented for all phases of pilot filter operation to date. Other aspects are also included in the following:

2. WELL STUDIES IN EFFLUENT IRRIGATION AREA

The bacteriological testing program of the downstream wells was completed during this period and the results are included with the chemical data and presented elsewhere in this report.

3. BACTERIOLOGICAL TESTING OF FILTER

During this project year bacteriological testing of the filter was conducted to determine not only the overall removals but the internal performance as well. The schedule as to time of sampling and location of sampling points varied in general to fit the mode of operation. Also included in this section are results obtained for the 5-day biochemical oxygen demand (B.O.D.) and the chemical oxygen demand (C.O.D.).

A. Method

Samples were tested for coliform bacteria, using the membrane filter method with M-Coliform Broth; fecal coliform using M-FC medium and fecal streptococci using M-Enterococcus Agar. During

early stages of operation, the standard multiple dilution MPN method for coliforms was used in parallel with the membrane filter but was discontinued. Standard plate counts (SPC) at 20 and 35° C. were also discontinued as not providing sufficient information to warrant the time spent.

B.O.D. and C.O.D. determinations were carried out by methods presented in "Standard Methods of Analysis For Water & Wastewater", 12th ed.

B. Results

Tables 1, 2, 3, and 4, summarize the results for all four of the major operational phases to date - Bay 1 loading, Bay 3 loading, loading of Bays 1, 2 and 3 for vertical operation and Bay 4 for conventional operation, and a repeat of Bay 3 loading following surface cleanup procedures. (Phases I, II, III and IV, respectively)

Bay 1 loading represents the longest travel distance through the filter. The data in Table 1 show that the major removals occur within the first few feet of vertical travel. The overall B.O.D. and C.O.D. reductions were 91 and 80 percent, respectively. (Phase I)

Table 2 shows the data for the first Bay 3 operation (Phase II). Again, considerable reductions in components occur in the initial vertical travel. It was apparent, however, from these data and from the tracing of flow patterns with dye that the warmer filter influent tended to override the cooler filter contents, causing a short-circuiting in the flow. The comparatively low results in the

TABLE 1

BAY 1 LOADING PHASE I
 August 9, 1966 to January 3, 1967 *
 (Bacteriological Data are Median Values)

Location	MF/100 ml		SPC/ml		B.O.D.	C.O.D.
	Coliform	Fecal Coliform	Fecal Streptococci	20° C.	35° C.	mg/l
Influent	2600 T	675 T	29 T	314 T (475 T)	280 T (1500 T)	(15) (65)
CMP 1 3	18 T	2.4 T	290	2 T (5.8 T)	13 T (92 T)	(7.6) (33)
6	8.5 T	220	100	700 (11 T)	2.1 T (30 T)	(5.9) (35)
9	7.9 T	240	50	200 (13 T)	4.0 T (26 T)	(4.4) (35)
12	-	-	-	(820)	(1.3 T)	(3.2) (27)
15	-	-	-	(480)	(1.3 T)	(3.5) (27)
CMP 2 (all levels)	21	0.4	1	71 (710)	510 (1.5 T)	(3.0) (25)
CMP 3 (all levels)	-	-	-	(420)	(2.5 T)	(2.5) (19)
CMP 4 S (all levels)	-	-	-	(330)	(910)	(2.7) (18)
CMP 4 N (all levels)	-	-	-	(230)	(1.4 T)	(2.5) (18)
Effluent	160	2	6.5	200 (175)	600 (375)	(1.3) (13)
Percent Removal					91	80

*Numbers in parentheses refer to data taken during an intensive sampling program Dec. 5, 12 and 19, 1966

TABLE 2
BAY 3 LOADING PHASE II
JAN. 5, 1967 TO APR. 10, 1967
(BACTERIOLOGICAL DATA ARE IN MEDIAN VALUES)

LOCATION	MF/100 ml			SPC/ml		B.O.D.	C.O.D.
	Coliform	Fecal Coliform	Fecal Streptococci	20°C	35°C	Mg/L	
INFLUENT	4900T	130T	85T	300T	580T	12	68
CMP-3 3 ft.	260T	3.7T	1.5 T	23T	38T	5.0	32
6	240T	2.0T	1.4T	18T	34T	7.4	30
9	140T	1.7T	890	7.9T	12T	5.1	27
12	4.6T	58	99	1.4T	7.1T	3.4	19
15	1.0T	49	67	650	1.8T	3.1	16
18	180	2	4	180	1.1T	2.2	10
CMP-4S 6	167T	3.9T	1.2T	13T	18T	3.6	32
9	28T	1.5T	430	2.8T	11T	3.6	23
12	23T	700	360	3.2T	5.4T	5.9	23
15	0.9T	56	43	1.5T	2.3T	4.9	14
18	0.8T	20	23	1.2T	2.2T	2.3	9
CMP-4N 9	35T	1.4T	490	8.5T	14T	3.3	18
15	2.3T	59	110	4.3T	6.5T	3.4	18
18	1.4T	40	25	2.7T	3.6T	2.6	10
EFFLUENT	1.3T	48	27	400	2.5T	1.8	21
PERCENT REMOVAL						85	69

lowest sampling lines indicate the presence of a static dead zone. In any case, B.O.D. and C.O.D. were reduced 85 and 69 percent, respectively.

The third phase of operation was the extreme in which Bays 1, 2, and 3 were operated vertically and Bay 4 was operated in conventional horizontal flow. Table 3 shows the results for this multiple (Phase III) operation. Included here are analyses of the water remaining on the bay surface from the previous day's loading. It will be noted that these surface values are very low - often lower than the effluent numbers. The high numbers found at the 3 to 6 foot levels might be due to a non-fecal coliform growth; however, this is not a certainty.

The removals during vertical operation were quite good considering the relatively short travel distances involved. However, the C.O.D.'s were only reduced about 63 percent. The high B.O.D. value for CMP 2 is a function of high nitrification in the sample since replicates after acidification and neutralization gave normal B.O.D. levels.

The horizontal operation for Bay 4 produced a good bacteriological quality, but had only a 74 percent C.O.D. removal. B.O.D. was removed efficiently; the jump at the effluent can be attributed again to active nitrification.

Data are also presented in Table 3 for the bacteriological content of the two sets of ponds - it will be recalled that the ponds are in series with flow split to Ponds B and C with overflow from B to A and C to D. The B.O.D. and C.O.D. of these ponds are

TABLE 3
MULTIPLE OPERATION
JUNE 8, 1967 TO DEC. 5, 1967
(BACTERIOLOGICAL DATA ARE MEDIAN VALUES)
PHASE III

Location	Coliform	MF/100ml		B.O.D.	C.O.D.
		Fecal Coliform	Fecal Strep-tococci	Mg/L	
Influent	3500T	530T	70T	13	68
Vertical Operation					
Bay 1 Surface	1.8T	640	19	-	57
CMP 1 3-6 ft.	8.6T	190	90	2.0	29
CMP 1 Effluent	2.5T	61	29	3.2	25
Bay 2 Surface	2.1T	200	16	-	46
CMP 2 3-6 ft.	25T	80	28	2.0	27
CMP 2 Effluent	2.5T	90	48	8.5	26
Bay 3 Surface	2.6T	73	33	-	53
CMP 3 3-6 ft.	10T	95	36	2.9	33
CMP 3 Effluent	4.1T	170	46	1.5	25
Horizontal Operation					
Bay 4 Surface	3.8T	300	34	-	53
CMP-4S 6 ft.	41T	790	830	5.3	42
CMP-4N 9 ft.	3.3T	140	65	3.3	38
CMP-4N 15 ft.	550	33	9	1.1	20
Effluent	230	15	30	5.7	18
			Perc. nt Removal		74%
Pond B	580	36	230	7.9	50
Pond A	130	45	160	8.4	64
Pond C	220	50	160	5.1	47
Pond D	150	18	73	4.9	58

increased over the effluents and bacteria are further reduced. Additional B.O.D. for the most part is a nitrification effect, whereas the increased C.O.D. is due to algal growth. Surface samples often showed a high C.O.D., also due to suspended algal growth.

The filter was returned to operation for the recently completed phase by loading Bay 3 after scarification of the surface followed by gravel replacement. The results of this Bay 3 operation (Phase IV) is shown in Table 4. These results should be compared with those shown in Table 2 for Bay 3 operation (Phase II). The data are quite comparable, particularly when one considers that the influent water is somewhat higher in strength due to operational problems and changeovers at the sewage treatment plant. The C.O.D. was reduced 76 percent with a B.O.D. reduction by CMP 4N of about 88 percent. The apparent B.O.D. increase is probably due to an active nitrifying flora in the samples. This high B.O.D. value is retained, however, since it probably more nearly represents the potential demand in the oxygen resources of the ponds. The pond C.O.D. showed the expected increase due to algal growth.

In summary it has been shown that the overall removal of coliform, fecal coliforms and fecal streptococci are very good within much less than the travel distance available. The B.O.D. of various effluents also were apparently high at times; however, this has been shown to be due to the presence of an active nitrifying flora and is a future drain on the pond dissolved oxygens. C.O.D. reductions were greatest where the longest travel times and/or distance was provided.

TABLE 4
BAY 3 LOADING - PHASE IV
DEC. 5, 1967 TO APR. 18, 1968
(BACTERIOLOGICAL DATA ARE IN MEDIAN VALUES)

Location	<u>MF/100 ml</u>			<u>B.O.D</u>	<u>C.O.D.</u>
	Coliform	Fecal Coliform	Fecal Streptococci	Mg/L	
Influent	7500T	720T	110T	27	105
CMP-3 Surface	390T	2.3T	800	-	84
CMP-3 3-9 ft.	110T	16T	1.1T	5.2	37
CMP-4S 6'	32T	2.0T	150	6.6	33
CMP-4S 12'	28T	1.8T	100	6.5	33
CMP-4N 9'	23T	950	100	3.4	30
CMP-4N 15'	5.8T	330	88	3.3	27
Effluent	670	76	43	9.4	25
			Percent Removal		76%
Pond B	-	-	-	-	59
Pond A	-	-	-	-	67
Pond C	-	-	-	-	54
Pond D	-	-	-	-	54

4. CHLORINATION

A series of preliminary experiments have been carried out to determine the chlorine demand of filter effluents. Figure 1 shows a composite for six of these runs of the residual after 30-minute contact time. The demand for a 0.1 mg/l residual seems to be less than about 0.5 mg/l.

Figure 2 shows the effect of varying dosages on the coliform and fecal streptococci content during several of these runs. The data appear to separate into two curves of different slopes indicating that coliform and fecal streptococci are not equally susceptible to disinfection. From the data, however, it would appear that a bacteriologically "safe" water has been obtained with dosages in the order of 1-1.5 mg/l of chlorine. Further work must be done to confirm this and perhaps more importantly to determine the dosages that are required to inactivate viruses. Studies in this direction are currently being carried on with the Department of Microbiology group.

5. EFFLUENT POTENTIAL FOR ALGAL GROWTH

Of interest to this study was some assessment of the capacity of various effluents to support and allow for algal proliferation. Ideally a minimum aftergrowth is desirable. Practically, it is a question of which effluent by its composition produces the least algae.

T.W.R. P.

CHLORINE RESIDUALS FOR PILOT FILTER EFFLUENT
30 MINUTE CONTACT TIME

EXPLANATION:

- PFE (CMP 3) 7-27-67
- PFE (SUMP) 7-27-67
- ▲ PFE (SUMP) 3-6-68
- ▽ PFE (SUMP) 3-12-68
- PFE (SUMP) 3-26-68
- PFE (SUMP) 4-9-68
- PFE (SUMP) 4-23-68

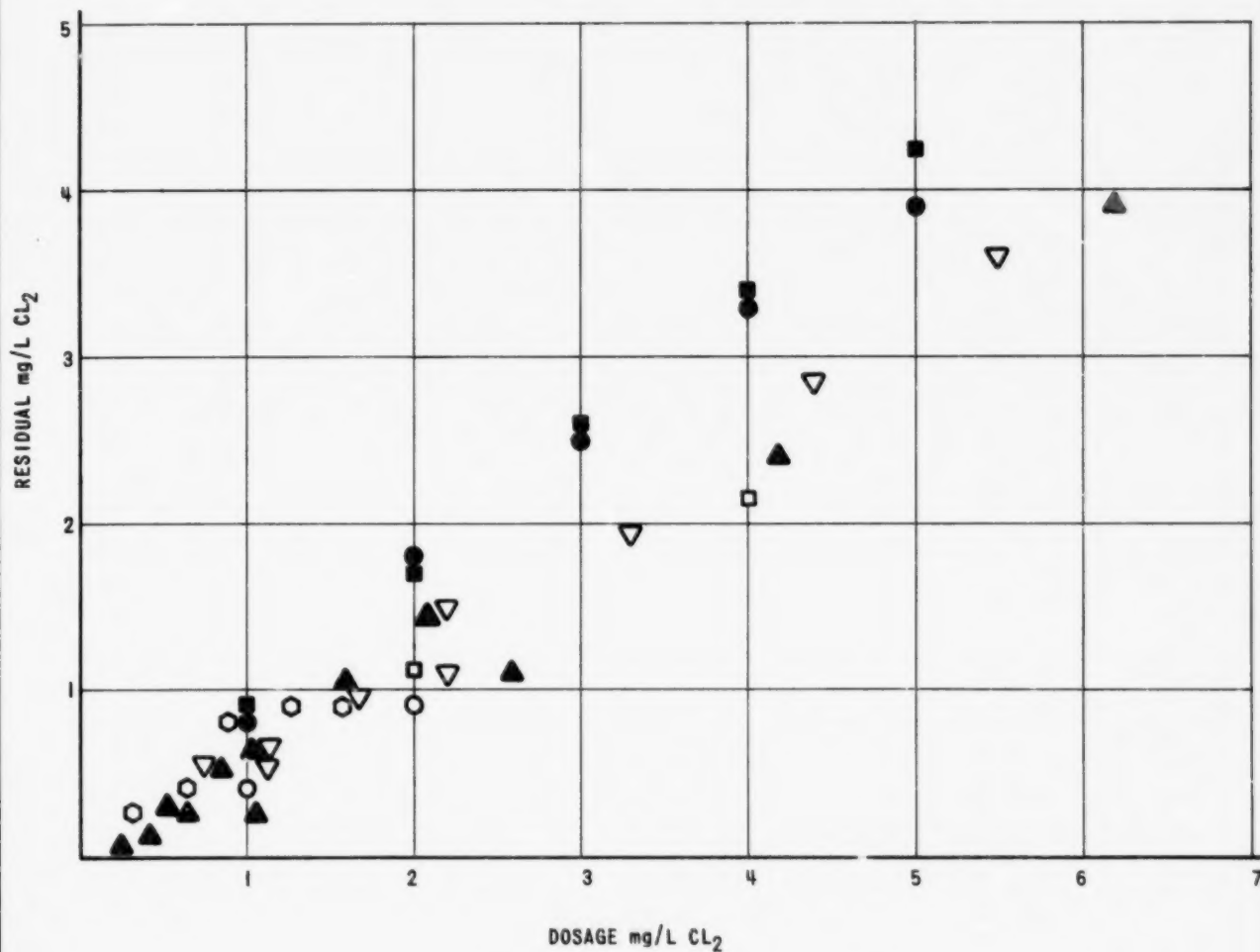


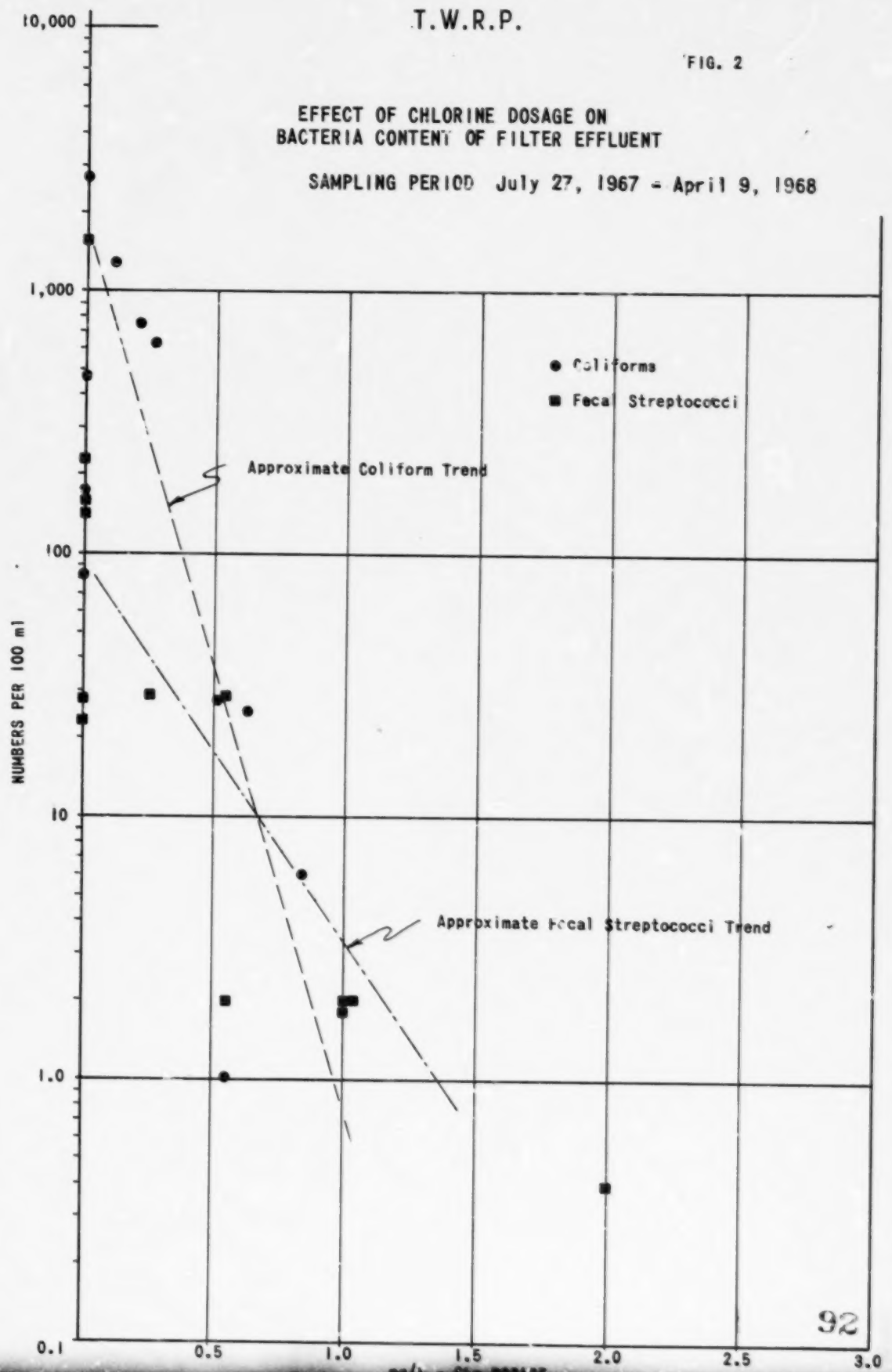
FIG. 1

T.W.R.P.

FIG. 2

EFFECT OF CHLORINE DOSAGE ON
BACTERIA CONTENT OF FILTER EFFLUENT

SAMPLING PERIOD July 27, 1967 - April 9, 1968



A. General Procedure

Various combinations of effluents and seed were used. One hundred ml portions were placed in 250 ml Erlenmeyer flasks on an orbital shaker under continual fluorescent lighting at 20° C. Periodically the samples were removed and the "growth" as represented by turbidity was measured at 450 millimicrons using a Spectronic-20 with a 1-inch cell.

B. Specific Runs and Results

Three runs of those conducted are reported here as illustrations:

Run 3

In this experiment samples of effluent from vertical operation of Bay 1 and the sump (Bay 4) were taken and seeded with either Pond B or Pond C water (10% by volume).

Figure 3 shows that Pond B alone produced a greater increase in growth (turbidity) than did Pond C alone. CMP-1 seeded with Pond B also was greater than when Pond C was the seed. The sump seeded with either Pond B or C lagged behind the CMP-1 growth although the final levels were higher.

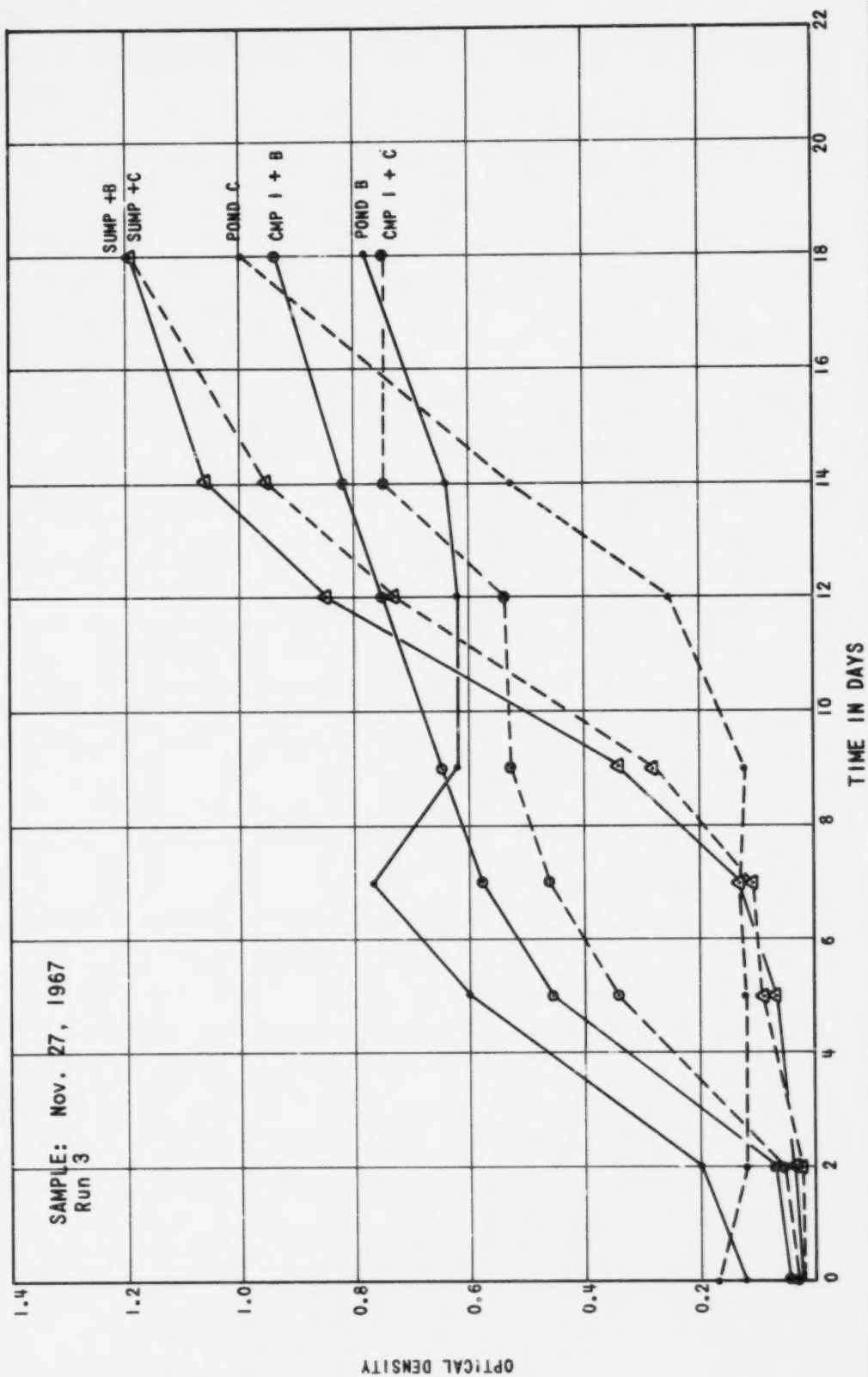
Figure 4 shows the effect of varying effluent mixtures seeded with either B or C. Initially, the growth increases with the percent CMP-1 in the mixture. In 9-12 days the roles were reversed.

Run 4

The results from the previous run suggested that perhaps the nitrogen form was critical. The vertical operation had

T.W.R.P.
OPTICAL DENSITY OF FILTER EFFLUENTS SEEDED
WITH POND WATER (10%)

FIG. 3

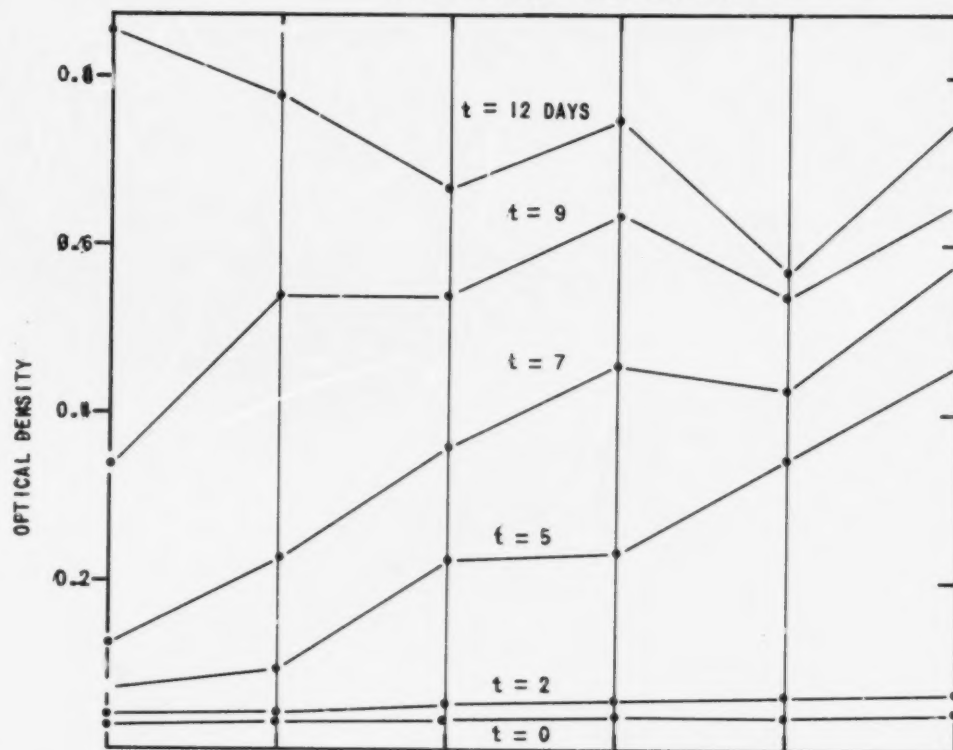


T.W.R.P.
EFFLUENT MIXTURES

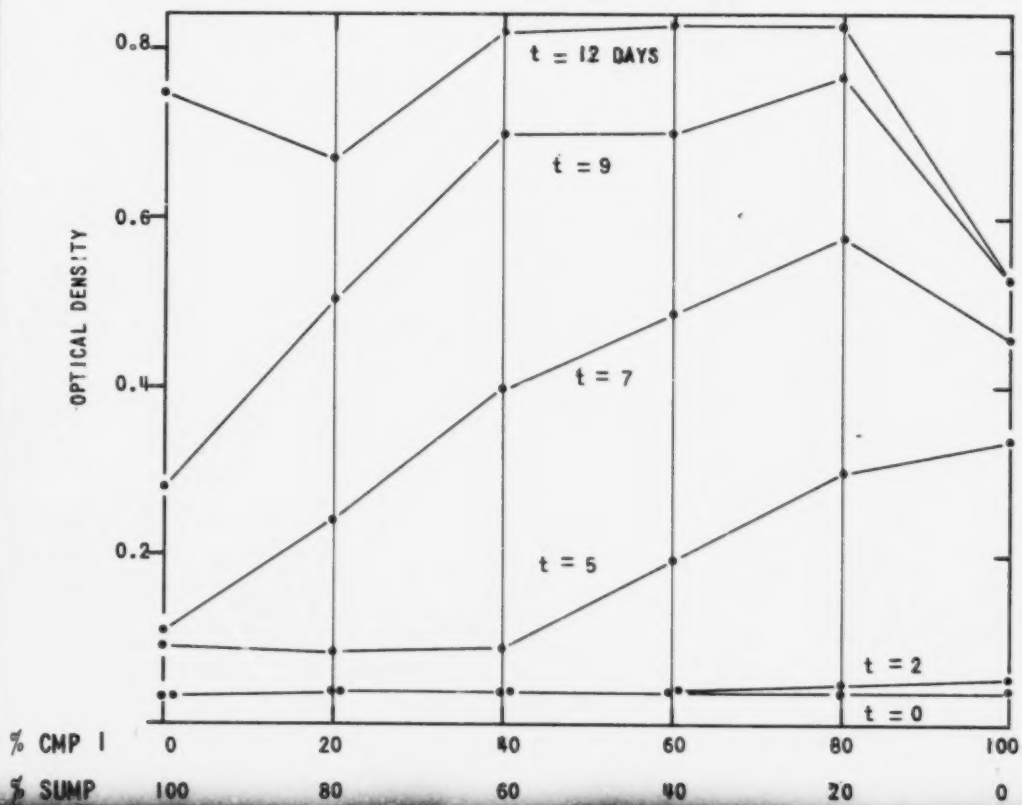
FIG. 4

SAMPLES: Nov. 27, 1967 Run 3-

CMP 1 - SUMP PLUS 10% POND B



CMP 1 - SUMP PLUS 10% POND C



$\text{NH}_3\text{-N}$ as the predominant form whereas $\text{NO}_3\text{-N}$ was high in the sump.

A similar series was set up with a 1% pond seed and 10 mg/l of either $\text{NO}_3\text{-N}$ or $\text{NH}_3\text{-N}$ added. CMP 4N samples taken from the 9 and 15 ft. lines were used. Here the 4N samples would be virtually identical to the sump except for differences in the nitrogen form. Ammonia-N would predominate in the 4N samples.

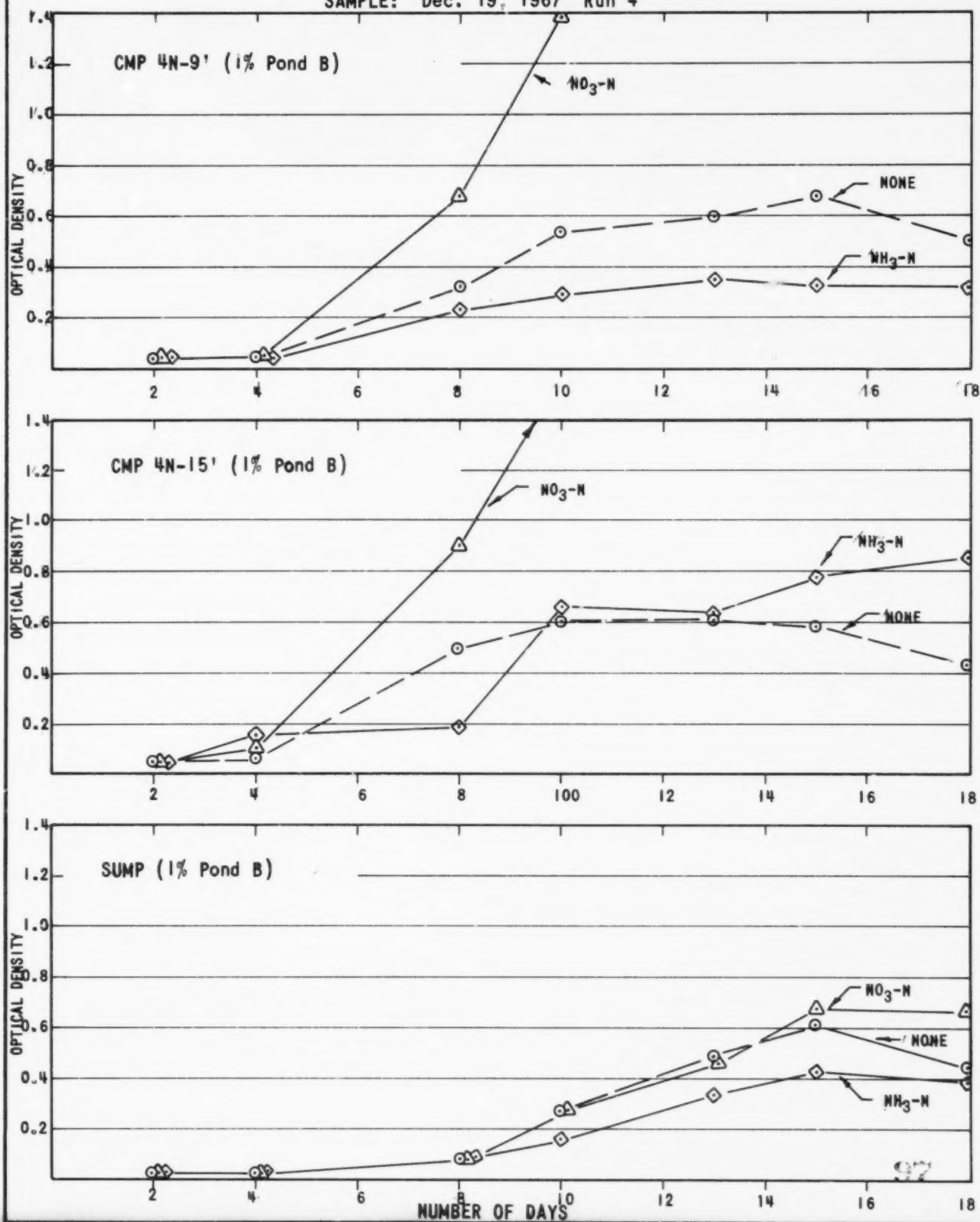
Figures 5 and 6 show the results of this run. In virtually all cases $\text{NO}_3\text{-N}$ stimulated growth. In some cases $\text{NH}_3\text{-N}$ depressed growth. The greatest increases were in the 4N samples even if no nitrogen were added. Use of B.O.D. dilution water seeded with either Pond B or C and with added nitrogen is shown in Figure 7.

Contradictions are evident. It might appear on comparing internal effluents with the sump that the greater growth was due to $\text{NH}_3\text{-N}$ being the better nitrogen source. The addition of $\text{NO}_3\text{-N}$ showed this not to be true. Indeed, it would have been a surprise were it true.

A subsequent run has produced virtually identical results. There remains considerable work to be done to resolve this question.

T.W.R.P.
OPTICAL DENSITY OF FILTER EFFLUENTS
WITH POND B AND ADDED NITROGEN (10 mg/l.)
SAMPLE: Dec. 19, 1967 Run 4

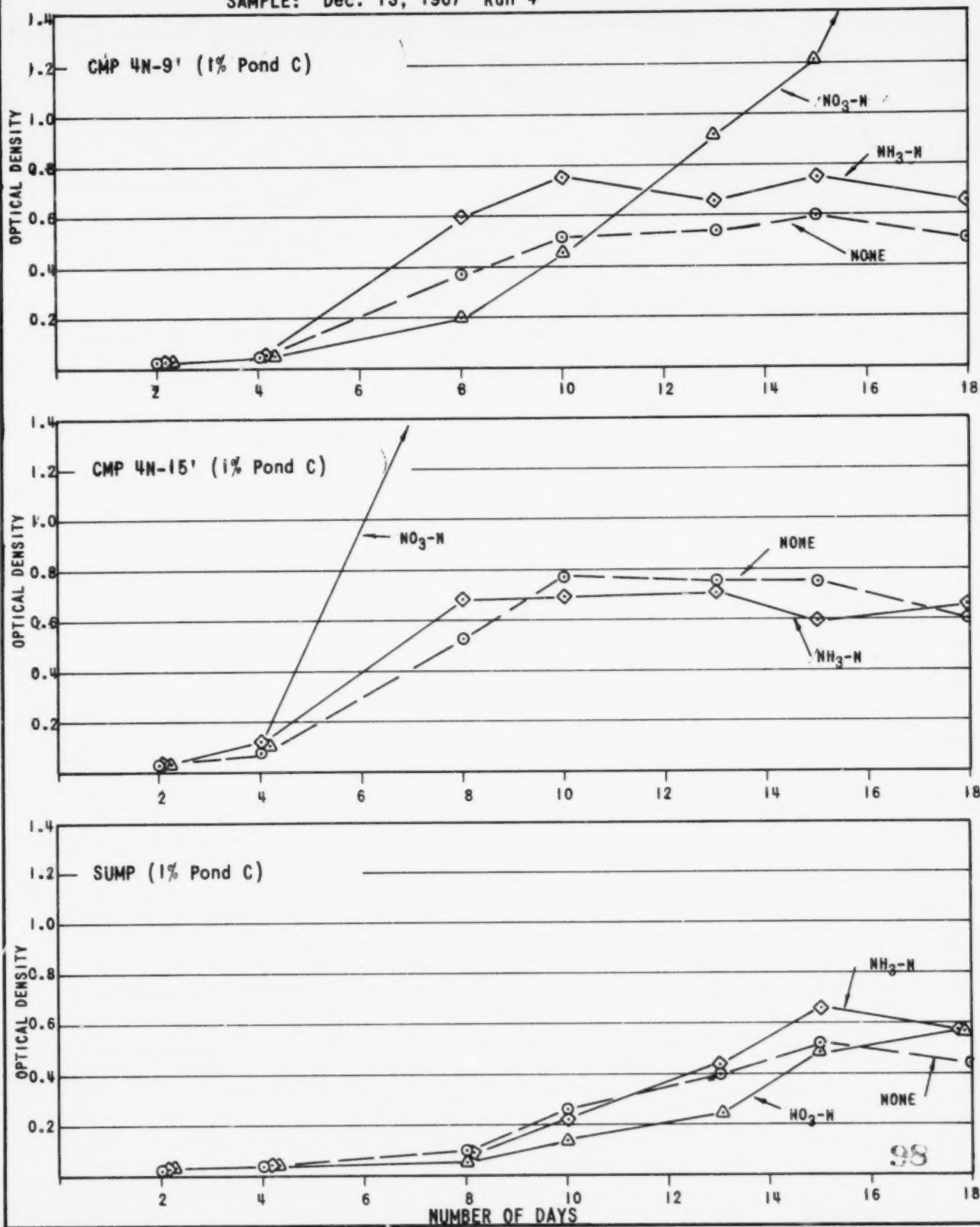
FIG. 5



T.W.R.P.
OPTICAL DENSITY OF FILTER EFFLUENTS
WITH POND C AND ADDED NITROGEN (10 mg/L)

FIG 6

SAMPLE: Dec. 13, 1967 Run 4

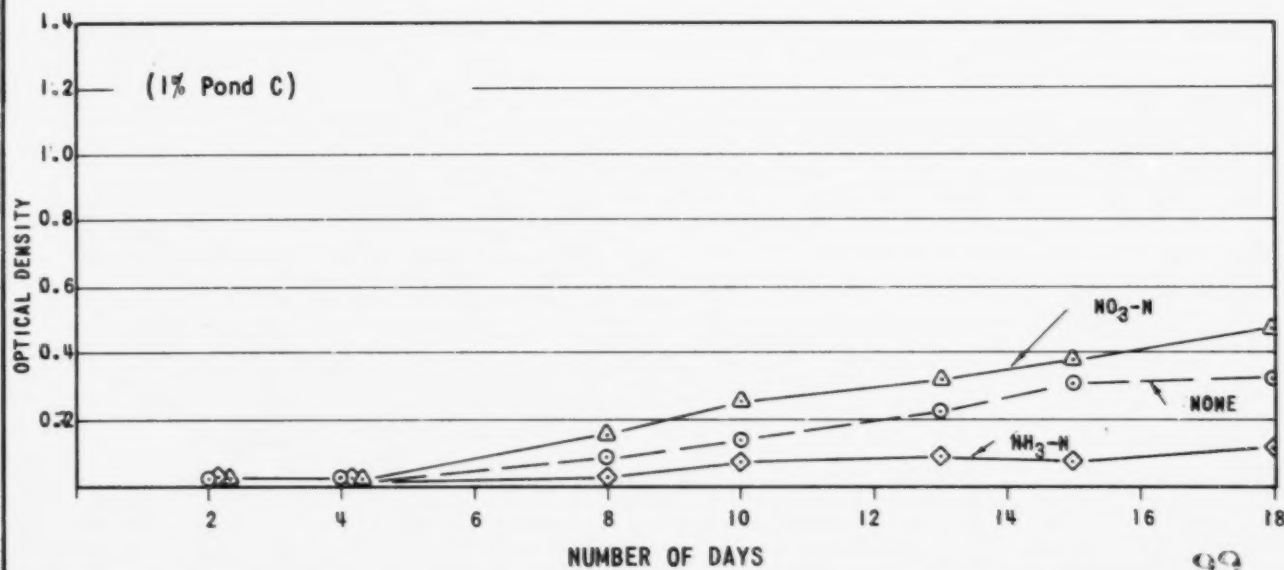
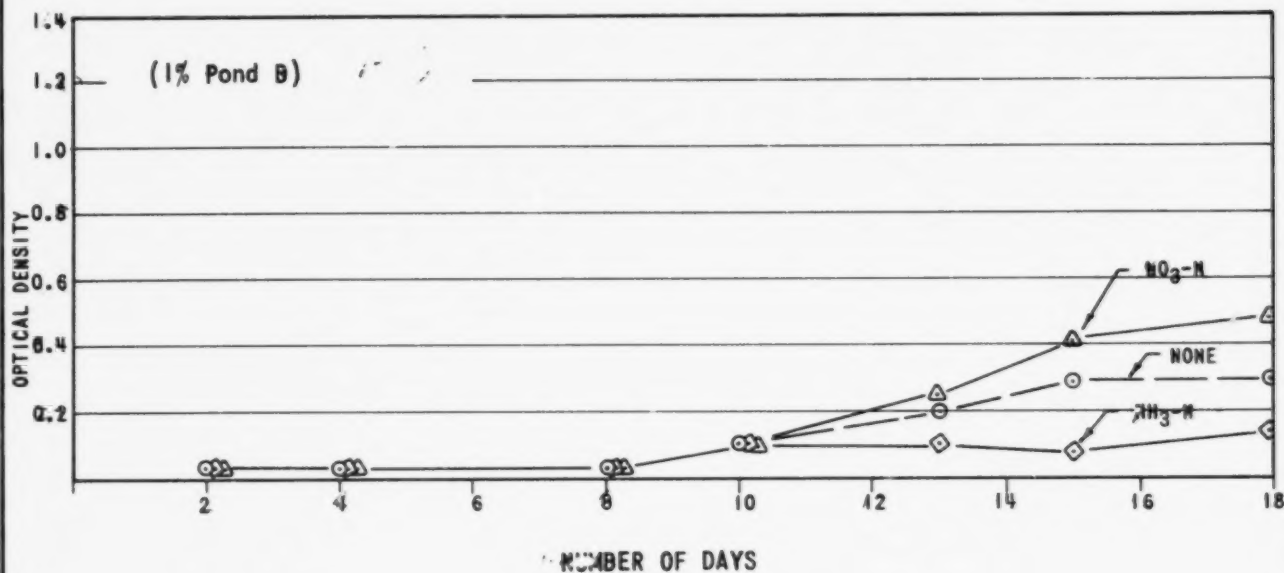


T.W.R.P.

FIG. 7

GROWTH IN B.O.D. DILUTION WATER USING
1% POND SEED AND ADDED NITROGEN
(10 mg/L AS N ADDED)

SAMPLE: Dec. 13, 1967 Run 4



CHAPTER VI

VIROLOGY

1. INTRODUCTION

Described in this section are the virological and limited bacteriological aspects of treatment plant and pilot filter study, including quantitative procedure evaluations.

2. VIROLOGICAL ASPECTS

A. Raw Sewage and Secondary Effluents. Table 1 lists the data on these preliminary studies. This work was carried out early (4/66 to 11/66) in the TWRP in order to indoctrinate our personnel with the water processing and subsequent viral detecting procedures. No effort was made to identify all the isolates detected in these raw and secondary wastewaters and, thus, the results are recorded simply as the percentage frequency of virus detected in the specimens.

B. Pilot Filter - Phase 1. On October 1, 1966, the new earth pilot filter became operative and our principal efforts were concentrated in processing water from the pilot filter influent (PFI) and the pilot filter effluent (PFE). During the period of Phase 1 operation Basin 1 loading (10/66 to 12/66) 28 PFI and 18 PFE samples were processed. The comparative results by two processing procedures (ultracentrifugation versus membrane concentration) are presented in Table 2. It is clear that the ultracentrifugation procedure was slightly superior to the membrane concentration method in the percentage frequency of viruses detected, total number of viruses isolated, and different types of viruses identified.

TABLE 1
DETECTION OF ENTEROVIRUSES IN SEWAGE, ACTIVATED SLUDGE, AND TRICKLING
FILTER EFFLUENTS BY TWO PROCESSING METHODS USING PRIMARY HUMAN AMNION+

	Ultracentrifugation			Membrane Concentration		
	Sewage	Activated Sludge	Trickling Filter	Sewage	Activated Sludge	Trickling Filter
No. Samples	4*	2**	2***	4*	6**	2***
No. Virus Positive Samples	3	2	2	4	2	2
Per Cent Frequency of Virus Detection	75	100	100	100	33	100

- + Samples from 4/66 to 11/66.
 * Three 100 ml grab samples and one 48 hr. immersed gauze pad (one-100 ml sample negative)
 ** Gauze pads immersed 48 hr.
 *** One 100 ml grab sample and one 48 hr. immersed gauze pad.
 * One-quarter to one-half gallon grab samples.
 ** One-half to three-quarter grab samples (two one-half gallon sample positive)
 *** One-half gallon grab samples.

TABLE 2

Detection of enteroviruses in pilot filter influent (PFI) and effluent (PFE) by two processing methods using primary human amnion.

PHASE 1 - BASIN I LOADING (10/5/66 to 12/27/66)

	ULTRACENTRIFUGATION*		MEMBRANE CONCENTRATION	
	PFI	PFE	PFI**	PFE***
No. of Samples	18	10	10	8
No. of Virus Positive Samples	14	4	4	2
Per Cent Frequency of Virus Detection	77.7	40	40	25
Total Virus Isolates	25	5	4	2
Virus Types Identified	Polio 1, 2, 3 Echo 7, 8, 11, 15, 20	Echo 16, 20	Echo 20	Echo 20

* Gauze pad immersed 48 hr to 1 wk.

** One-half to 1.4 gallons of sample processed.

*** Three and one-half to 5 gallons of sample processed.

Various studies dealing with the effectiveness of cell culture type in detecting viruses from PFI or PFE by the ultracentrifugation procedure are presented in Tables 4 and 5. The data clearly indicates that Human Amnion cultures were more effective for detecting echoviruses whereas Monkey Kidney cultures were more suitable for detecting polioviruses. The relative proportion of virus types isolated from PFI and PFE by ultracentrifugation is presented in Table 6. Similar data are available for the membrane virus concentration procedure and will be included in the final report.

C. Pilot Filter - Phase 2. During Phase 2 operation Basin III loading (1/67 to 4/67) 21 samples from each of the two types of water were processed. Comparative data of the same two processing procedures is presented in Table 3. In this series the ultracentrifugation method was again superior to the membrane concentration procedure for PFI but the opposite was true for PFE. No significant difference was observed in the total number of viruses isolated or the different types of viruses identified.

D. Tap Water Control. During the period when the Basins of the Pilot Filter were drained in preparation for Phase 3 (loading all 4 Basins and vertical pumping from the lowest levels of CMP 1, 2, and 3), three tap water samples were processed by the gauze-pad ultracentrifugation procedure. The gauze pads were suspended in aluminum cylinders with a continuous flow of tap water over the pads for 7 days. No virus was detected in these three tap water samples.

TABLE 3

Detection of enteroviruses in pilot filter influent and effluent
by two processing methods using primary human amnion

PHASE 2 - BASIN III LOADING (1/9/67 to 4/10/67)

	ULTRACENTRIFUGATION**		MEMBRANE CONCENTRATION	
	PFI	PFE	PFI***	PFE#
No. of Samples	13	13	8	8
No. of Virus Positive Samples	9	1	4	2
Per Cent Frequency of Virus Detection	69	8	50	25
Total Virus Isolates	12	1	7	2
Virus Types Identified	Polio 1, 2 Echo 11 Echo 7	Echo 11	Polio 1, 2 Echo 6, 7, 9 Adeno	Echo 11

** Gauze pad immersion 1 week.

*** One-half to one gallon of sample processed.

Four and one-half to 5 gallons of sample processed.

TABLE 4

EFFECTIVENESS OF CELL TYPE IN DETECTION OF PFI VIRUSES
BY ULTRACENTRIFUGATION*

RUN	HUMAN AMNION	MONKEY KIDNEY**
1	Negative	Negative
2	Echo 7, 20	Polio 1
3	Echo 7	Polio 1
4	Echo 11	Echo 8, Polio 2
5	Negative	Polio 1
6	Echo 7	Echo 7, Polio 1, 3
7	Echo 7, Polio 1	Polio 2
8	Echo 15, 20	Echo 8, Polio 3
9	Echo 20	Polio 3
10	Echo 20	Echo 18, unidentified
11	Negative	Polio 1
12	Negative	Negative
Detection frequency	8/12 66%	10/12 84%
Frequency isolation echoviruses	8/8 100%	4/10 40%
Frequency isolation polioviruses	1/8 9%	9/10 90%

* Basin I Loading (10/5/66 to 12/27/66)

** African Green Monkey Kidney Cells

TABLE 5

EFFECTIVENESS OF CELL TYPE IN DETECTION OF PFE VIRUSES
BY ULTRACENTRIFUGATION*

RUN	HUMAN AMNION	MONKEY KIDNEY**
1	Negative	Negative
2	Negative	Negative
3	Negative	Negative
4	Negative	Negative
5	Echo 20	Negative
6	Negative	Negative
7	Negative	Negative
8	Echo 16, 20	Negative
9	Echo 20	Negative
10	Echo 20	Negative
Detection frequency	4/10 40%	0 0%

* Basin I Loading (10/5/66 to 12/67/66)

** African Green Monkey Kidney Cells

TABLE 6

RELATIVE PROPORTION OF TOTAL VIRUS TYPES ISOLATED FROM
PFI AND PFE BY ULTRACENTRIFUGATION*

ECHOVIRUSES	POLIOVIRUSES
ECHO 7 5 X	POLIO 1 6 X
ECHO 8 2 X	POLIO 2 3 X
ECHO 11 1 X	POLIO 3 2 X
ECHO 15 1 X	
ECHO 16 1 X	UNIDENTIFIED 1 X
ECHO 18 1 X	
ECHO 20 8 X	
Total echo isolates 19	Total polio isolates 11
Total isolates 31	Total unidentified 1

* Basin I Loading (10/5/66 to 12/27/66)
Primary human amnion and african green
monkey kidney cells used.

E. Pilot Filter - Phase 3. During Phase 3 operation (6/67 to 12/67) Basin 1 to 4 loading with vertical pumping from the lowest levels of CMP 1, 2, and 3, 119 water samples were processed and tested for viruses by the classical ultracentrifugation procedure. The results are presented in Table 7. The data indicate no significant differences between the sampling points (possible exception CMP 3 which appeared to have the best quality water by two of the virological parameters studied - fewer virus isolates and only one virus type).

The lower per cent frequency of virus detection during Phase 3 operation even for PFI samples may be partially explained on the high temperature in Tucson during the summer and fall months.

F. Quantitative Studies 1) Standard Millipore membrane concentration, Phase 1 and 2. The value of the membrane concentration procedures lies in its ability to concentrate and detect sub-infectious quantities of virus from large volumes of natural waters. This permits assessment of virus pollution in terms of virus infective particles per unit volume of water. Examples of the type of quantitation possible by this method are presented in Tables 8 and 9. An estimate of the viral infective units per gallon of PFI and PFE are presented for Basin I and III loading of the Pilot Filter. Such quantitative data permit calculations on the effectiveness of the Pilot Filter in removing viruses. The estimated percentage virus reduction by the Pilot Filter was 93% with Basin I loading compared to 98% with Basin III loading.

TABLE 7

Detection of enteroviruses in pilot filter influent (PFI) and effluent (PFE) with vertical pumping within the pilot filter's first three basins (CMP 1, 2, and 3) using the ultracentrifugation procedure and primary human amnion.

PHASE 3 - Basin 1 to 4 Loading (6/5/67 to 12/14/67)

SAMPLE SITE					
	PFI	CMP1	CMP2	CMP3	PFE
No. samples Collected	26	25	21	21	26
No. of Virus Positive Samples	6	4	7	3	4
Per Cent Frequency of Virus Detection	23	16	33	14	15
Total Virus Isolates	8	9	7	3	6
Virus Types Identified	Polio 1, 2, 3 Echo 7	Polio 1, 2, 3 Echo 7	Polio 1, 2, 3 Echo 7	Echo 7	Polio 1, 2, 3 Echo 7

TABLE 8

ESTIMATE OF VIRAL INFECTIVE UNITS PER GALLON OF PFI AND PFE
 PROCESSED BY THE MEMBRANE CONCENTRATION PROCEDURE AND
 DETECTED BY PRIMARY HUMAN AMNION*

PHASE 1 - BASIN I LOADING (10/5/66 to 12/27/66)

Run No.	Date	PFI	PFE
47	10/20/66	36.8	
52	11/15/66	432.0	
55	11/18/66	102.9	
56	11/21/66		36.9
71	12/20/66	86.4	
Mean		65.8	4.6
Estimated % Virus Reduction			93%

* Based on 4 virus positive samples out of 10 for PFI and
 1 virus positive samples out of 8 for PFE (1 PFE did not
 become positive until the 1st passage).

TABLE 9

ESTIMATE OF VIRAL INFECTIVE UNITS PER GALLON OF PFI AND PFE
PROCESSED BY THE MEMBRANE CONCENTRATION PROCEDURE AND
DETECTED BY PRIMARY HUMAN AMNION*

PHASE 2 - BASIN III LOADING (1/9/67 to 4/10/67)

RUN NO.	DATE	PFI	PFE
78	1/12/67		2.9
84	1/31/67	52.8	
87	2/2/67		2.2
88	2/7/67	165.6	
93	2/13/67	39.6	
101	2/27/67	26.4	
Mean		35.5	0.64
Estimate % Virus Reduction			98%

* Based on 4 virus positive samples out of 8 for PFI and
2 virus positive samples out of 8 for PFE.

One would expect greater virus removal with Basin I loading rather than with Basin III since the water travels a greater horizontal travel distance through the Pilot Filter (approximately 290 and 150 ft. for Basin I and III, respectively). However, other factors enter the picture such as seasonal effects (higher virus pollution of water during the fall than the winter) and temperature effects (viruses survive better in colder water).

G. Quantitative Studies 2) Comparative processing procedures using poliovirus seeded waters. - In spite of the quantitative approach permitted by the Millipore membrane procedure there were certain disadvantages of the method which precluded its use as a routine procedure. The most important was cost. The initial expense of the elaborate filtering equipment as well as the continuing cost of membrane filters limited the number of water samples processed per week. In addition, time involved in processing a sample due to membrane filter clogging was economically not feasible. One modification that Wallis & Melnick made in their procedure was to use Dowex resin in place of protamine sulfate to remove more membrane coating components (MCC). Theoretically, then, Dowex resin should permit faster rates of water filtration by removing the MCC which plug up the membrane pores and at the same time permit a more efficient adsorption of the viruses to the membranes.

In order to investigate this new modification as well as to determine how effective the membrane viral concentration procedure

actually was in terms of virus recovery in our wastewaters, we initiated a series of quantitative poliovirus seeding studies. In these experiments, polio 1 was added to PFI and PFE water samples at a known concentration immediately prior to processing. Polio 1 produces plaques in African green monkey kidney (AGMK) or HE_p 2 cells in 24 hours, whereas indigenous viruses in the wastewaters are incapable of demonstrating any effects until four to seven days. Thus, it is possible to compare different viral concentration procedures in terms of the concentration of seeded virus recovered.

Initial studies were designed to determine whether the volume of the sample, the size of the AP-20 prefilter, the size of the viral-adsorption membrane, or the concentration of polio 1 added to the water samples influenced the percentage of polio virus recovered when the samples were processed by the standard membrane concentration procedure using protamine sulphate. The results are presented in Table 10. The data clearly indicate that none of the factors appreciable affect virus recovery. The surprising finding in these studies was the fact that poliovirus recoverability was extremely poor ranging from 0.6 to 5%. The next series of studies were concerned with learning where virus was being lost in the standard (membrane virus concentration) water processing method. Two experiments were carried out with PFI water in which the filtrate was tested for virus concentration after each step in the processing procedure. These data are presented in Table 11. The majority of seeded virus is

TABLE 10

Virus recoverability after seeding wastewater samples with Polio 1 and processing by the standard multiple Millipore membrane viral concentration procedures*

Sample No.	Volume sample (ml)	AP-20 Prefilter Size (mm)	0.45 μ Membrane Size** (mm)	Polio 1 input (PFU/ml)***	Virus Recovered 0.45 μ Membrane (%)
<u>Pilot Filter Influent (PFI)</u>					
1	2000	142	47	3	0.6
2	4000	142	47	3	1.1
3	225	47	47	4200	1.7
4	225	47	47	5900	3.8
5	4000	142	142	4300	3.0
6	2000	142	47	25	1.3
<u>Pilot Filter Effluent (PFE)</u>					
1	4000	142	47	40	5
2	4000	142	47	2.5	1
3	4000	142	47	2	3

* All samples were filtered through 142 mm. 0.22 μ membranes to remove bacteria after AP-20 prefiltration.

** Size of the viral adsorption membrane

*** PFU/ml - plaque forming units per ml.

TABLE 11

Loss of seeded Polio 1 during processing steps by the multiple Millipore membrane viral concentration technique*

	<u>% of Polio 1 Lost</u>	
	Sample 1	Sample 2
After seeding	0	0
After gross debris removed by AP-20 prefilter	34	ND**
After bacteria removed by 0.22 μ membrane	54	ND
Total loss during 1st two steps of processing	88	90.8
After virus adsorption to 0.45 μ membrane	8.2	6.2
Total virus lost in filtrates	96.2	97.0

* Samples 1 and 2 were 225 and 4000 ml of PFI water samples respectively

** Not done individually

lost during the first two processing steps (88 to 90.8%), when the water is freed of gross debris and bacteria. According to Wallis & Melnick no virus should be lost during these preliminary processing steps because the water should be hypotonic and, therefore, viruses should not adsorb to these membranes. This may be true for Texas sewage wastewater but apparently it is not true for Tucson's wastewaters. In any case, of the remaining virus available for recovery (12 and 9.2%), there was a further virus loss (8.2 and 6.2%) due to failure of polio to adsorb to the 0.45 μ HA membrane thus resulting in a total virus recovery of only 3.8 and 3% respectively. Further studies had to be carried out to determine how to eliminate such losses of virus in processing our wastewaters.

In an attempt to eliminate the virus lost by failure of the viruses to adsorb to the final 0.45 μ HA Millipore membrane, Wallis & Melnick incorporated a Dowex resin filtration step in place of protamine sulphate treatment. We decided to compare the effectiveness of Dowex resin with the standard protamine sulphate method and at the same time test an Al (OH)₃ viral-adsorption technique (also championed by Wallis & Melnick). For this purpose PFI and PFE water samples were individually filtered through AP 20 prefilters and 0.22 μ HA membranes to remove all bacteria. The sterile water samples were then seeded with polio 1 at a known concentration and divided into three equal one gallon portions which were processed by the three different techniques. The results are presented in Table 12. Aluminum hydroxide virus-adsorption procedure was far superior to the other two procedures. Dowex resin method showed some improvement over the standard protamine

TABLE 12

Comparison of three quantitative processing procedures for the concentration of viruses in large volumes of wastewater*

Method	Polio 1 Recovered %	
	PFI	PFE
Millipore Membrane protamine sulphate	28	3.4
Millipore Membrane Dowex resin	32	29
Al (OH) ₃ viral-adsorption	100	100

- * Three gallon samples were filtered through AP-20 prefilters and 0.22 μ membranes to remove bacteria prior to seeding with Polio 1 virus. One gallon aliquots were then processed by each of the three methods.

sulfate membrane concentration technique for PFE but not for PFI sample. Substantiation of these findings are now in progress. Nevertheless, we have initiated the use of the quantitative $\text{Al}(\text{OH})_3$ virus-adsorption procedure in our routine monitoring of wastewaters.

Unfortunately, the problem of virus loss during the first two steps of processing (AP-20 prefilter and 0.22 μ , HA membrane filtration to remove bacteria) is still being resolved. Two approaches to this problem are presently being investigated. One involves the use of serum-coated filters for the first two steps. Pretreating the AP-50 filter eliminated all the virus lost in the first step. Similar treatment of 0.22 μ HA Millipore membrane has reduced the virus lost, but a 30% loss still occurs. Presently we are testing 0.20 μ or 0.45 μ Gelman membranes to remove bacteria without losing virus since apparently Gelman membranes do not adsorb viruses. The second approach involves the destruction of bacteria with disinfectant treatment after virus-adsorption to $\text{Al}(\text{OH})_3$. Preliminary results on three disinfectants used in this manner are presented in Table 13. Ether treatment of $\text{Al}(\text{OH})_3$ processed concentrate destroyed 99% of the bacteria in PFI sample and permitted 100% recovery of the added polio-virus. Whether ether treatment will be superior to Gelman membrane filtration in terms of detecting a higher concentration of indigenous viruses in PFI samples remains to be demonstrated.

H. Quantitative Studies 3) Pilot Filter - Phase 4 - During Phase 4 operation (2/68 to 3/68) Basin III loading 16 water samples were processed by the $\text{Al}(\text{OH})_3$ virus-adsorption procedure. Precoating

TABLE 13

Comparative effect of three disinfectants used to destroy bacteria on the recovery of added Polio 1 in a PFI sample

Disinfectant Treatment*	Polio 1 Recovered %
Ether (25%)	100
Chloroform (25%)	89
Roccal (1:450)	33

- * PFI sample processed by the $AL(OH)_3$ viral-adsorption procedure and the viral concentrate treated with disinfectant for 18 hours at $4^{\circ}C$. With each disinfectant, 99% of the bacteria were destroyed.

of AP-20 pads were used to remove gross debris and Gelman 0.20 μ membranes were used to remove bacteria of PFI samples. For PFE samples the concentration of bacteria is low enough to control by using three times the level of antibiotics instead of membrane filtration. The results, incorporating these new innovations, are presented in Table 14. Although our sample size of 8 PFI and 8 PFE is as yet not large enough, this new quantitative procedure appears to give a more realistic value of virus concentrations per gallon of water. Moreover, for the first time a water processing procedure is being used which yields 100% virus detection in PFI samples. The estimated percentage virus reduction by the pilot filter in this series was 97.2%. Now that we have a practical quantitative viral assessment procedure for grab samples, we can proceed with chlorination studies with PFE samples. Such studies have been initiated in collaboration with Civil Engineering Department. They will include the effect of different levels of chlorine on the indigenous viruses in PFE as well as on various prototype enteroviruses added at known low concentrations.

3. LIMITED BACTERIOLOGICAL ASPECTS

A. Total Bacterial Counts and Coliform Density. - One phase of the limited bacteriological studies was to determine the total bacterial and coliform density of raw sewage and various secondary effluents of the Tucson Plant in order to learn the best quality effluent for charging the Pilot Filter. This study was carried out from May 1966 through January 1967. Briefly summarized, the data indicated that, on the basis of total bacteria and coliform density, activated sludge effluent was the best quality of water

TABLE 14

Estimate of the number of viral infective units per gallon of pilot filter influent and effluent processed by the aluminum hydroxide viral-adsorption procedure.

Phase 4 - Basin III Loading (2/9/68 to 3/15/68)

Run No.	Date	VIU* Per Gallon	
		PFI	PFE
1	2/9/68	615	0
2	2/16/68	43.4	32.2
3	2/23/68	202.8	0
4	3/1/68	12	0
5	3/5/68	190	0
6	3/8/68	73.2	0
7	3/12/68	1	1
8	3/15/68	43.2	0
Mean	(VIU/GALLON)	147.4	4.1
Estimated % Virus reduction			97.2%

*VIU - Virus infective units

and should be used first to load the Pilot Filter. If a second source of water is needed, the holding or oxidation pond effluent was a better quality water than trickling filter effluent which was the poorest quality of all secondary effluents studied. On the basis of percentage reduction of coliforms from raw sewage, activated sludge was first with 88.6%, holding pond effluent was second with 85.1%, holding pond influent was third with 56.2%, and trickling filter was again last with only 39.8% reduction.

B. Salmonella-Shigella Detection & Recovery - A second phase of the bacteriological studies was directed towards the development of appropriate procedures for the detection of Salmonella-Shigella species in Tucson's wastewater. It was felt that the absence of Salmonella-Shigella in PFE would be an excellent indicator of the bacteriological safety of such renovated water. However, after we detected Salmonella in only one out of 132 water samples from sewage and various secondary treated effluents using six different concentration and detection methods, we decided that the Salmonella-Shigella parameter could not be used. Nevertheless, it was advisable to investigate why our detection of these organisms was so poor.

For this purpose, we inoculated sewage, PFI, and PFE samples with known numbers of Salmonella typhimurium which had been previously acclimated to growth in sewage. The results of these studies are presented in Table 15. Briefly the data indicate that the indigenous bacterial population in Tucson's sewage interferes with the recovery of added Salmonella. When S. typhimurium was

TABLE 15

The recovery of Salmonella typhimurium which has been added to raw sewage, pilot filter influent, and pilot filter effluent

Type of Material	Number of Organisms added/ml	Ratio of added to indigenous organisms	Isolation Index as Percent*
Raw sewage	5,000,000	1:5	94
	5,000	1:5,000	25
	500	1:50,000	17
	50	1:500,000	0
Pilot Filter influent	188	1:5,425	16
	141	1:14,822	7
Pilot Filter effluent	205	1:164	75
	123	1:20	86
	21	1:1,640	50
	12	1:200	86

* The isolation index indicates the number of colonies which proved to be Salmonella divided by the number of colonies examined. This term was used in a paper by Wang et al.

added to sewage, PFI, or PFE, the recoverability depended on the ratio of added *Salmonella* to the indigenous bacterial population. Furthermore, the data presented in Table 16, clearly indicate that when *S. typhimurium* was added to the same water samples after all the indigenous organisms had been removed by membrane filtration (Millipore 0.22 μ), the *Salmonella* not only survived but increased in number. Similar results were obtained for a *Shigella flexnerii* strain as well as with a centrifugation method to remove indigenous organisms rather than membrane sterilization. It was clear from these findings that further efforts to detect *Salmonella* or *Shigella* in our wastewater would be useless. However, as a by-product of these studies we became interested in the bacteriophages penetrating the pilot filter. Presently a quantitative method for detecting low concentrations of bacteriophages has been developed for assessing phages in PFI and PFE. It is possible that a phage to enterovirus ratio could be determined which might validate the use of phage numbers as a rapid indirect indicator of the presence of animal viruses in renovated wastewater.

TABLE 16

Growth of added Salmonella typhimurium in membrane filtered wastewaters*

Type of Wastewater	Run No.	Number of Salmonella per ml	
		Average inoculum Added	After 24 hours (X10 ⁴)
Raw sewage	1	130	30
	2	170	400
	3	142	300
Pilot filter influent	1	146	3
	2	126	3
	3	159	0.8
Pilot filter effluent	1	123	30
	2	178	300
	3	179	700

* Average count of duplicate plates from each 10 ml quantity of membrane filtered water sample. Physiological Saline (0.85%) and tap water control tubes inoculated with equivalent numbers of Salmonella showed no multiplication of the organisms but a reduction ranging from 16 to 70% for Saline and 1 to 96% for tap water.

CHAPTER VII
FISHERY INVESTIGATIONS

1. OBJECTIVES

Research objectives have been pursued as scheduled and preliminary data has indicated that the methods employed to evaluate the fishery potential are satisfactory.

2. PROGRAM & RESULTS

On October 1, 1967 channel catfish were stocked at rates of 1000, 2000, and 3000 fish per acre in three experimental ponds. In mid-January these fish had doubled their weight irrespective of the stocking rates. The weight gain was better than expected.

Rainbow trout were stocked at rate of 1000 fish per acre in the fourth pond on October 16, 1967. At the end of February the trout more than tripled their weight. There was however, a high degree of growth variability and survival rates were mediocre.

Phytoplankton blooms were generally very good and kept dissolved oxygen concentrations high, but an occasional die-off left the pond waters oxygen deficient (See Table 1). Zooplankton density was also good but variable.

Bottom organisms (benthos) populations were more stable than plankton and reproduction appeared to offset the amount consumed by the fish. This is expected to change as water temperatures rise, but the degree of change is unpredictable.

TABLE 1
MEAN DISSOLVED OXYGEN CONCENTRATIONS AND pH IN EXPERIMENTAL
PONDS -- TUCSON WASTEWATER RECLAMATION PROJECT

January 30-31, 1968

	Pond A	Pond B	Pond C	Pond D	pH
Maximum S**	19.0	25.0	22.0	12.0	9.1
Maximum B***	12.0	17.0	10.0	5.0	
Minimum S	16.0	16.0	10.0	4.0	8.7
Minimum B	10.0	16.0	9.0	3.5	

February 9-10, 1968

Maximum S	15.0	5.0	17.0	16.0	8.9
Maximum B	5.0	4.0	11.0	9.5	
Minimum S	8.0	3.5	9.0	8.5	8.9
Minimum B	5.0	3.0*	8.5	8.5	

February 19-20, 1968

Maximum S	15.0	24.5	23.0	20.0	9.1
Maximum B	7.0	12.0	12.0	7.5	
Minimum S	8.0	12.0	12.0	9.0	9.0
Minimum B	7.0	12.0	9.0	9.0	

March 1-2, 1968

Maximum S	10.0	14.0	13.5	9.0	9.0
Maximum B	5.0	11.5	8.0	3.0	
Minimum S	4.0	7.0	4.5	2.0	8.8
Minimum B	4.0	6.0	4.5	1.0	

Note: Benthos relatively stable
Zooplankton showing slight increase

- * Mortality of trout significant
- ** Surface
- *** Bottom

Water quality, as indicated by various analyses (See Chapter 4, Table 17), appears to be favorable for fish production except during extended cloudy periods when phytoplankton die-off occurs. It is during these periods that low dissolved oxygen concentrations prevail.

Oxygen is vital to sustain a recreational fishery. It must be understood that oxygen is produced by phytoplankton simultaneously with synthesis of new organic matter and ultimately the secondary B.O.D. will be equal to the oxygen produced. Consequently, phytoplankton oxygen production should not be the sole expected source of the dissolved oxygen supply. Pre-aeration of filter effluent derived from vertical pumping (containing NH_4) prior to entering the experimental ponds would be beneficial.

CHAPTER VIII
EFFLUENT RECHARGE AREA

Comprehensive treatment of the chemical and bacteriological quality considerations of well waters obtained within the area of effluent recharge influence is contained in Chapter IV of the First Annual Report (1965-66) of the Tucson Wastewater Reclamation Project (July 1966).

Additional evaluation is contained in the Northwest Area Well Field Development Report (September 1967) which was prepared after detailed study of the information available on well construction and water quality, and is appended to this Progress Report.

Heretofore, unavailable detailed results of the bacteriological sampling and sanitary survey are included here to complete the library of valuable data collected. An arbitrary overall classification for sanitary evaluation was set up as follows:

Good - All results passable on bacteriology.

Fair - Results more often good than bad.

Poor - Results usually or always poor (irrigation wells are included in this classification generally as a result of field inspection of construction.)

In summary, the 103 wells sampled for bacteriological quality are classified individually in Table B, 1 through 15, and result in classification totals as follows:

Good	-	32
Fair	-	21
Poor	-	42
Unclassified	-	<u>8</u>
		103

Well numbers used in Table B are common to those used in Appendix A (Record of Wells and Water Quality) of the Northwest Area Well Field Report, and can be easily located on Plate 1 of the same report.

NORTHWEST AREA DEVELOPMENT STUDY
TUCSON WASTEWATER RECLAMATION PROJECT
SANITARY MICROBIOLOGY OF WELLS

WELL	NAME	DATE	MF/100 ml				SPC/ml		SANITARY SURVEY & GENERAL REMARKS
			Colif.	F.C.	F.S.		20°C	35°C	
T11S R11E 36 ccd	Paycoll Farms	6-67	34	0	0		-	-	FAIR - Seal OK; irrig. 100' E. lined ditch 50' E.
		6-66	0	0	0		4	42	
		1-66	0	-	0		3	29	
T12S R11E 1 dba	Beard	6-67	0	0	0		-	-	GOOD - Two septic tanks; 150' S. & 100' W.
		6-66	0	0	0		1	4	
		1-66	0	-	0		0	0	
T12S R12E 6 acc	Gibbon's Trucking	6-67	13	0	0		-	-	FAIR - OK; no obvious prob- lems
		6-66	0	0	0		0	12	
		1-66	0	-	0		14	15	
6 bdd	Apex Farms	6-67	4	0	9		-	-	FAIR - Irrig. 50 - 75' N & E.
		6-66	0	0	0		0	7	
		2-66	0	-	0		4	56	
6 dac	Brady	6-67	0	0	0		-	-	GOOD - Well seal OK; cows in immed. area; tile field and dry well for septic tank; 75 - 100' E.
		6-66	0	0	0		1	6	
		3-66	0	-	1		48	74	
		2-66	0	-	1		35	20	
7 caa	Benson	6-67	0	0	0		-	-	GOOD - Septic tank, 200' E.
		6-66	0	0	0		2	37	
		12-65	0	-	0		3	45	
8 abd	Rancho Grande	6-67	0	0	0		-	-	FAIR - Poor cover on elev. tank; horses 200' W.; irrig. E.
		6-66	0	0	0		0	0	
		3-66	0	-	0		36	48	
		2-66	2	-	1		>300	170	
		1-66	>200	-	21		>300	520	

NORTHWEST AREA DEVELOPMENT STUDY
TUCSON WASTEWATER RECLAMATION PROJECT
SANITARY MICROBIOLOGY OF WELLS

WELL	NAME	DATE	MF/100 ml			SPC/ml		SANITARY SURVEY & GENERAL REMARKS
			Colif.	F.C.	F.S.	20°C	35°C	
T12S R12E 8 bbb-1	(continued) Ariz. Portland Cem. Co.	6-67 12-65	8 0	0 -	0 0	- >300	- >300	FAIR - Good seal
8 acc	Ariz. Portland Cem. #4	6-67 6-66 12-65	13 0 1	0 0 -	0 0 0	- 15 14	- 45 848	FAIR - Seal OK; irrig. W. W.
8 dba	Cortaro Farms (8-J)	6-66 4-66 3-66	6 0 15	0 - -	0 0 4	3 17 54	1 4 68	POOR - Taken out of service; typical irrig. well
8 dac	Morito Water Co.	6-66 5-66 12-65	0 0 0	0 - -	0 0 0	0 4 74	21 15 1325	GOOD - Taken out
9 ccb	American Smelting & Refining Co.	6-67 6-66 5-66 12-65	0 0 0 0	0 0 - -	0 0 0 0	- 1 440 6	- 3 350 316	GOOD - Seal OK
15 cdd	Gluck	6-67 6-66 2-66	7 0 17	0 0 -	1 18 97	- 197 >300	- 421 >300	POOR - Gravity tank - poor construction, open; well OK; animals W. & W.
16 bba-1	Cortaro Farms (16-D-1)	6-67 5-66 3-66	2 15 0	0 - -	0 11 0	- 132 0	- >300 2	POOR - Irrig. well; no irrig. nearby
16 bba-2	Cortaro Farms (16-D-2)	6-67 8-66 3-66 12-65	21 1 0 1	0 0 - -	2 0 0 -	- 0 0 32	- 119 11 146	POOR - Irrig. well; no irrig. nearby

NORTHWEST AREA DEVELOPMENT STUDY
TUCSON WASTEWATER RECLAMATION PROJECT
SANITARY MICROBIOLOGY OF WELLS

WELL	NAME	DATE	MF/100 ml			SPC/ml		SANITARY SURVEY & GENERAL REMARKS
			Colif.	F.C.	F.S.	20°C	35°C	
T12S R12E 16 bdd	(continued) Cortaro Farms (16-F-1)	4-66 3-66	0 8	- -	0 37	5 210	9 308	POOR - Irrigation well
16 bcb-2	Cortaro Farms (16-L)	8-66 7-66	0 40	0 0	0 0	26 199	147 244	POOR - Irrigation well
17 daa	Cortaro Farms (17-I)	6-67 8-66 7-66 3-66	1 0 10 8	0 0 0 -	0 0 0 0	- 16 19 76	- 94 107 134	POOR - Irrigation well
17 ddd	Cortaro Farms (17-P-1)	6-67 3-66	11 0	0 -	0 0	- 0	- 7	POOR - Irrigation well
20 aad	Cortaro Farms (20-A)	6-67 8-66	1 52	0 0	0 0	- 48	- 67	POOR - Irrigation well
20 caa	Berwick	6-67 3-66 2-66 1-66	0 0 0 1	0 - - -	0 0 0 0	- 0 0 0	- 3 3 4	GOOD - Domestic; no obvious sources
21 baa	Cortaro Farms (21-C-2)	7-66 4-66 3-66	4 0 0	0 - -	0 0 0	112 194 >300	>300 350 440	POOR - Irrigation well
21 bab-2	Cortaro Farms (21-C)	8-66 7-66 4-66 3-66	0 1 0 26	0 0 - -	5 1 0 0	3 4 3 1	4 55 2 5	POOR - Irrigation well

NORTHWEST AREA DEVELOPMENT STUDY
TUCSON WASTEWATER RECLAMATION PROJECT
SANITARY MICROBIOLOGY OF WELLS

WELL	NAME	DATE	MF/100 ml				SPC/ml		SANITARY SURVEY & GENERAL REMARKS
			Colif.	F.C.	F.S.		20°C	35°C	
T12S R12E 21 bdd	(continued) Cortaro Farms (21-F)	6-67	0	0	0		0	7	POOR - Irrigation well
		7-66	2	0	0		102	311	
		4-66	5	-	22		30	63	
		3-66	21	-	0		115	143	
21 cad	Cortaro Farms (21-K)	7-66	60	0	1		94	544	POOR - Irrigation well
		4-66	4	-	0		15	144	
		3-66	64	-	0		>300	490	
21 dcd	Cortaro Farms (21-O)	6-67	0	0	0		-	-	POOR - Irrigation well
		8-66	0	0	0		0	33	
		7-66	0	0	0		5	115	
		3-66	0	-	0		80	59	
22 bdd	Cortaro Farms (22-D)	6-67	2	0	0		-	-	POOR - Irrigation well
		6-66	0	0	0		35	95	
		3-66	0	-	0		>300	>300	
22 bdd-1	Western Meat Co.	6-67	0	0	0		-	-	GOOD - Stock pens 150' W. Pooled water around pump, seal OK
		6-66	0	0	0		0	0	
		5-66	0	-	0		3	7	
		3-66	0	-	0		9	13	
		2-66	0	-	0		3	2	
		1-66	1	-	2		13	15	
22 dcd	Curtis	6-67	29	0	5		-	-	POOR - Well seal good; elev. tank partially open; irrig. all around
		6-66	0	0	0		0	3	
		5-66	>200	-	8		>700	1700	
		3-66	1	-	>200		>300	>300	
		2-66	0	-	11		>300	-	
		1-66	0	-	1		483	62	

NORTHWEST AREA DEVELOPMENT STUDY
TUCSON WASTEWATER RECLAMATION PROJECT
SANITARY MICROBIOLOGY OF WELLS

WELL	NAME	DATE	MF/100 ml				SPC/ml		SANITARY SURVEY & GENERAL REMARKS
			Colif.	F.C.	F.S.		20°C	35°C	
T12S R12E 22 ddb	(continued) Cortaro Farms (22-P)	6-67 6-66 3-66	111 0 0	0 0 -	18 0 0		- 4 17	- 5 13	POOR - Irrigation well
25 cac	Cortaro Farms (25-K)	6-67 8-66 6-66 4-66 3-66	71 10 5 2 0	2 19 6 - -	0 0 0 0 5		- 89 56 1 3	- 84 320 19 45	POOR - Irrigation well; occasional submerged outlet; dairy waste pits, 200' M.W.
26 add	Hartman	6-67 6-66 3-66 2-66 2-66	0 75 13 15 1	0 0 - - -	0 17 63 20 1		- >300 6 11 16	- >300 35 110 27	GOOD - New well POOR - Old well - abandoned
26 adb	Shamrock Dairy	6-67 6-66 2-66	0 0 0	0 0 -	0 0 0		- 0 278	- 4 >300	GOOD - Good seal, splash apron
26 bca	Cortaro Farms (26-E)	6-67 6-66 3-66	0 0 0	0 0 -	0 0 0		- 53 >300	- >300 430	Irrigation well No obvious sources POOR
26 dba	Cortaro Farms (26-J-2)	6-67 8-66 6-66	1 3 0	0 0 0	0 1 0		- 1 14	- 21 33	POOR - Irrigation well No obvious sources
26 dbd-2	Cortaro Farms (26-J-3)	6-67 8-66 6-66 3-66	0 0 0 0	0 0 0 -	0 0 0 0		- 40 46 4	- 44 232 10	POOR - Irrigation well No obvious sources

NORTHWEST AREA DEVELOPMENT STUDY
TUCSON WASTEWATER RECLAMATION PROJECT
SANITARY MICROBIOLOGY OF WELLS

WELL	NAME	DATE	MF/100 ml			SPC/ml		SANITARY SURVEY & GENERAL REMARKS
			Colif.	F.C.	F.S.	20°C	35°C	
T12S R12E 27 bcc	(continued) Omstead	6-67	0	0	2	-	-	FAIR - Hoses 50' E., well OK
		7-66	0	0	0	0	10	
		1-66	0	-	0	0	8	
27 cbb-1	Cortaro Farms (27-L)	6-67	9	0	0	-	-	POOR - Typ. irrigation well; irrigation nearby
		4-66	0	-	0	1	5	
27 cbb-2	Johnson	6-67	0	0	0	-	-	GOOD - Good sanitary area
		7-66	0	0	0	3	107	
		1-66	0	-	0	1	37	
34 dbb	Emmons	6-67	0	0	0	-	-	GOOD - Good seal
		7-66	0	0	0	0	2	
		2-66	0	-	0	1	245	
34 dbd	Meech	6-67	0	0	9	-	-	FAIR - Fair seal
		7-66	0	0	0	9	362	
		3-66	0	-	0	27	86	
		2-66	0	-	0	6	32	
		2-66	0	-	8	1	10	
34 ddb	Handy	6-67	2	0	0	-	-	GOOD - Good seal
		7-66	0	0	0	1	18	
		3-66	0	-	0	23	5	
		2-66	0	-	0	1	20	
		1-66	0	-	11	0	2	
34 dcc	Warren & Hanson	6-67	0	0	2	-	-	FAIR - Stables 400' S.
		7-66	0	0	1	10	14	
		1-66	0	-	0	1	1	

NORTHWEST AREA DEVELOPMENT STUDY
TUCSON WASTEWATER RECLAMATION PROJECT
SANITARY MICROBIOLOGY OF WELLS

WELL	NAME	DATE	MF/100 ml				SPC/ml		SANITARY SURVEY & GENERAL REMARKS
			Colif.	F.C.	F.S.		20°C	35°C	
T12S R12E 35 add	(continued) Cortaro Farms (35-H)	6-67	1	0	0		-	-	POOR - Irrigation well; irrigation and ponding on all sides. Poor seal.
		8-66	0	0	0		79	6	
		7-66	0	0	0		50	120	
		4-66	0	-	0		68	72	
			0	-	5		> 300	> 300	
36 bab	Cortaro Farms (36-C)	6-67	1	0	0		-	-	POOR - Irrigation well - oil contam. (?); horses 20' W. & S.; irrigation N.
		8-66	11	0	0		5	10	
		3-66	0	-	0		240	270	
36 cdc	Cortaro Farms (36-N)	6-67	2	0	0		-	-	POOR - Irrigation well Irrig. 100' E.; Oshrin channel 15'; poor seal
		6-66	0	0	0		147	218	
		3-66	0	-	0		5	84	
36 ddb	Simonsen	6-67	0	0	1		-	-	FAIR - Poor seal; septic tank 200' N. E.
		6-66	0	0	0		0	2	
		2-66	0	-	0		1	3	
36 das	S.P. Corral	6-67	0	0	0		-	-	GOOD - Domestic, OK
		6-66	0	0	0		145	155	
		12-65	0	-	0		2	64	
T12S R13E 27 cbb	Strickler	1-66	0	-	0		3	23	Unknown
27 cda	Pegler	1-66	0	-	0		19	12	Unknown
31 das-2	Rancho Toda La Vista	1-66	0	-	0		11	27	Unknown
32 bcc	Osborne	1-66	0	-	0		0	7	Unknown
33 aab	Currier	1-66	0	-	0		0	0	Unknown

NORTHWEST AREA DEVELOPMENT STUDY
TUCSON WASTEWATER RECLAMATION PROJECT
SANITARY MICROBIOLOGY OF WELLS

WELL	NAME	DATE	MF/100 ml				SPC/ml		SANITARY SURVEY & GENERAL REMARKS
			Collif.	F.C.	F.S.		20°C	35°C	
T13S R12E 1 aba	Pulley	6-67 6-66 12-65	0 0 0	0 0 -	0 0 0		- 0 3	- 295 14	GOOD - Rabbit pens 25' N.; good seal
1 aba-1	Truman	6-67 6-66 12-65	7 >200 0	0 0 -	0 0 0		- 24 53	- >300 33	POOR - Chickens all about
1 ba	Contreras	6-67 6-66 12-65	0 0 0	0 0 -	0 0 0		- 18 8	- 127 314	GOOD - Unknown
1 bab	Burrola	6-66 12-65	0 0	0 -	0 0		0 12	1100 144	
1 bba	Valles	6-67 6-66 5-66 3-66 2-66 12-65	0 0 0 0 0 0	0 0 - - - -	0 0 0 0 0 0		- 4 3 3 2 7	- 263 450 >300 2 71	GOOD - Unknown
1 bda	Cortaro Farms (1-F)	6-67 6-66 3-66	6 0 0	0 0 -	0 0 0		- 14 10	- 320 16	POOR - Irrigation Detergent foam
2 add	Logan Water Co. (#5)	6-67 12-65	0 0	0 -	0 0		- 2	- 64	GOOD - Fair well seal

NORTH-EAST AREA DEVELOPMENT STUDY
TUCSON WASTEWATER RECLAMATION PROJECT
SANITARY MICROBIOLOGY OF WELLS

WELL	NAME	DATE	MF/100 ml			SPC/ml		SANITARY SURVEY & GENERAL REMARKS
			Colif.	F.C.	F.S.	20°C	35°C	
T13S R13E 5 bba	Cortaro Farms (S-D)	6-67 4-66	0 0	0 -	0 0	- 3	- 95	POOR - Irrigation well
5 ccb	Hilmer	6-67 6-66 1-66	11 0 0	0 0 -	0 0 0	- 0 17	- 79 9	FAIR - Turkey farm; no info. on wells, septic tanks, etc.
6 bba	Dobbs	6-67 6-66 1-66	33 0 0	0 0 -	2 0 0	- 3 7	- 410 16	POOR - Horses 200' S. Poor seal, septic tank adjacent
6 cdd	Shoemaker	6-67 6-66 5-66 3-66 2-66 12-65	>300 0 0 0 0 9	0 0 - - - -	28 0 0 0 0 0	- 8 156 151 23 142	- 2100 101 270 48 >300	POOR - Casing open, cows all around; irrigation all around
6 dda	Shoemaker	3-66 2-66 12-65	0 0 0	- - -	5 7 0	220 113 156	194 85 490	FAIR - Cannot be flamed; irrigation all around
7 adc	Rillito Race Track	6-66 3-66 2-66 12-65	0 7 0 >200	0 - - -	0 1 0 98	4 50 >300 >300	107 >300 47 >300	FAIR - Unknown
7 caa	Shoemaker	6-67 6-66 5-66 3-66 12-65	>200 >2000 20 0 33	0 24 - - -	>200 1100 >200 0 0	- 930 650 44 148	- 12,000 970 200 >300	POOR - Well sealed OK; irrigation well only; inter- section of Rillito & Santa Cruz River

NORTH-EAST AREA DEVELOPMENT STUDY
TUCSON WASTEWATER RECLAMATION PROJECT
SANITARY MICROBIOLOGY OF WELLS

WELL	NAME	DATE	MF/100 ml			SPC/ml		SANITARY SURVEY & GENERAL REMARKS
			Colif.	F.C.	F.S.	20°C	35°C	
T13S R13E 7 cdd	(continued)	6-67	3	0	3	-	-	FAIR - Horses 75'; septic tanks, 250' S.E., down slope
	Walker	7-66	0	0	0	0	7	
		12-65	0	-	0	33	63	
8 acc	Greenfield School	6-67	3	0	0	-	-	GOOD - Pump seal OK; septic tank 500' N. E.
		6-66	0	0	0	2	1300	
		5-66	0	-	0	5	6	
		3-66	0	-	0	0	2	
		1-66	0	-	1	15	9	
		12-65	0	-	0	5	16	
8 bdd	Lattimore	6-67	8	0	0	-	-	POOR - Ponding water, irrig. all around area; cattle, horses adjacent to well
		6-66	0	0	7	0	2250	
		5-66	0	-	94	19	27	
		3-66	3	-	0	79	116	
		2-66	0	-	11	129	123	
		12-65	77	-	3	79	134	
8 ccc	Sunset Dairy	6-67	8	0	0	-	-	FAIR - Irrig. 100' E.; cows 500' N. W.; well seal OK
		6-66	0	0	0	1	550	
		12-65	0	-	0	1	13	
8 cda	Griggs	6-67	>200	0	37	-	-	POOR - Domestic, alongside Rillito River; gravity tank in line of poor quality
		6-66	0	0	2	0	observed mold	
		5-66	>200	-	80	770	360	
		3-66	27	-	35	>3000	>3000	
		1-66	11	-	1	218	27	
		12-65	37	-	15	73	97	
8 cdd	Weylor	6-67	83	0	1	-	-	POOR - Leaky seal, 1/8 th mile from Rillito
		6-66	47	8	1	0	17	
		5-66	0	-	0	8	13	
		3-66	7	-	0	9	36	

NORTHWEST AREA DEVELOPMENT STUDY
TUCSON WASTEWATER RECLAMATION PROJECT
SANITARY MICROBIOLOGY OF WELLS

WELL	NAME	DATE	MF/100 ml			SPC/ml		SANITARY SURVEY & GENERAL REMARKS
			Colif.	F.C.	F.S.	20°C	35°C	
T13S R13E 8 cdd (continued)	(continued)	1-66 12-65	0 >200	- -	0 5	22 246	30 287	GOOD - Adjacent to Rillito still OK, chickens 100' S. & 150' N.; 150' S., septic tank
16 bdd	Johnson	6-67 6-66 12-65	0 0 0	0 0 -	0 0 0	- 0 16	- 440 >300	
16 ccc	Gilbert Pump Co.	6-67 6-66 1-66	0 0 0	0 0 -	0 0 0	- 1 4	- 48 2	
16 ccd	City of Tucson (Z-3)	1-66	0	-	0	5	8	
17 abb	Ingalls	6-67 6-66 3-66 3-66 1-66 12-65	7 1 0 0 0 >200	0 0 - - - -	1 13 0 197 5 1	- - 9 95 23 445	- 1370 17 >300 124 >300	POOR - Doubtful seal; 1/8th mile, Rillito River
17 caa	Casa Motel	6-67 6-66 1-66	0 0 0	0 0 -	0 0 0	- 5 >300	- >300 >300	
17 cad	Edwards	6-67 6-66 3-66 2-66 12-65	128 0 0 0 8	0 2 - - -	>200 91 0 0 0	540 2 22 7	1010 5 16 60	
								GOOD - Well seal broken
								POOR - Well seal fair; irrigation 200' N.

NORTHWEST AREA DEVELOPMENT STUDY
TUCSON WASTEWATER RECLAMATION PROJECT
SANITARY MICROBIOLOGY OF WELLS

WELL	NAME	DATE	MF/100 ml				SPC/ml		SANITARY SURVEY & GENERAL REMARKS
			Colif.	F.C.	F.S.		20°C	35°C	
T13S R13E 17 dad	(continued) Laguna School	6-66 12-65	0 0	0 -	0 0		2 7	28 13	GOOD - No longer used - on City water
17 ddd	Smith	6-67 6-66 3-66 12-65	>200 >200 22 4	0 0 - -	>200 360 35 29		- 33 24 24	- 1530 148 91	POOR - City sewage pond, 200' S. W.; pump OK
18 abb	Chandler	6-67 5-66 3-66 2-66 12-65	0 0 0 0 0	0 0 - - -	0 0 0 0 4		- - 126 17 21	- - >300 >300 17 11	GOOD - Septic tanks 100' N.; opening at top well casing 1/8 mi. W. of Santa Cruz R.
18 acs	Howard	6-67 5-66 3-66 2-66 12-65	>300 >200 >200 0 >200	0 0 - - -	175 >200 >200 4 >200		- 3 >300 >300 >300	- 12 >300 >300 >300	POOR - 1/8 mi. W. to Santa Cruz River; poor pump seal; septic tanks 100' S.E.
18 ccb	Bentley	5-66 12-65	0 0	0 -	0 0		7 10	153 59	
20 dcd	Pima County	12-65	0	-	-		0	>300	
21 abd	Syler	6-67 6-66 12-65	0 1 0	0 0 -	0 0 0		- 0 7	- 3 12	Good - Septic tank 100' E. OK
21 das	Argust	6-67 5-66 3-66 2-66	41 0 0 0	0 - - -	0 0 0 15		- 10 63 6	- 17 >300 9	FAIR - Severed (?) No obvious sources

NORTHWEST AREA DEVELOPMENT STUDY
TUCSON WASTEWATER RECLAMATION PROJECT
SANITARY MICROBIOLOGY OF WELLS

WELL	NAME	DATE	MF/100 m ³			SPC/m ³		SANITARY SURVEY & GENERAL REMARKS
			Colif.	F.C.	F.S.	20°C	35°C	
T13S R13E 21 dec	(continued) City of Tucson	2-66 12-65	0 0	- -	0 -	4 0	8 0	
27 cca	Town & Country Motel	6-67 6-66 12-65	15 0 0	0 0 -	3 0 0	- 1 23	- 4 >300	FAIR - Fair sanitary qual. No obvious sources
27 ccb	Arizona Ranch School	6-67 6-66 2-66 12-65	0 0 0 0	0 0 - -	0 0 0 -	- 2 4 0	- 0 10 11	GOOD - No obvious sources
27 cdd-2	Soil Conservation Serv.	6-67 6-66 3-66 2-66 12-65	11 0 0 0 0	0 0 - - -	29 2 24 15 10	- >300 144 75 103	- >300 >300 81 90	POOR - Possible oil leakage irrigation use
27 cdd-1	Soil Conservation Serv.	6-67 6-66 12-65	0 0 0	0 0 -	0 0 0	- 0 12	- 1 9	GOOD - No obvious sources
27 dcB	Town & Country Motel	12-65	0	-	0	0	6	No map listing (?)
28 cca	Johnson	6-67 2-66 12-65	0 0 0	0 - -	13 0 -	- 23 5	- 35 193	FAIR - Poor seal, septic tank 100' E.; Horses 100' NW
29 ada-1	Marsland	6-67 7-66 2-66 12-65	2 0 0 0	0 0 - -	0 0 0 -	- 1 7 11	- 7 >300 >300	GOOD - Septic tank 200' N. No obvious sources, const. OK

NORTHWEST AREA DEVELOPMENT STUDY
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SANITARY MICROBIOLOGY OF WELLS

WELL	NAME	DATE	MF/100 ml				SPC/ml		SANITARY SURVEY & GENERAL REMARKS
			Colif.	F.C.	F.S.		20°C	35°C	
T13 R13E 29 dda-1	(continued) Bergman	6-67	1	0	0		-	-	FAIR - Septic tank 100' N.E. Const. fair, high poodle population
		3-66	0	-	0		4	31	
		2-66	0	-	0		20	24	
		12-65	183	-	-		1250	>300	
33 abb	City Prison Farm	6-67	0	0	0		-	-	GOOD - No problem
		6-66	0	0	0		21	56	
		3-66	0	-	0		0	6	
		2-66	15	-	0		22	376	
		12-65	0	-	-		-	351	POOR - In middle of nursery septic tank 200' N. W.
33 dba	Silverbell Nursery	6-67	54	0	1		-	-	
		6-66	2	1	-		3	7	
		3-66	15	-	0		30	71	
		2-66	0	-	65		111	259	FAIR - Horses 75' W & 100'SE
		12-65	196	-	-		59	127	
33 dbb-2	Hayton	6-67	22	0	29		-	-	
		6-66	0	0	0		0	12	
		3-66	0	-	0		15	86	GOOD - No problem
		2-66	0	-	0		57	195	
		12-65	2	-	0		27	>300	
33 dbc	Nelson	6-67	0	0	0		-	-	
		6-66	0	0	0		0	5	POOR - Open port. on gravity tank
		12-65	0	-	0		0	2	
33 dac	Silverbell Guest Ranch	6-67	1	0	1		-	-	
		3-66	2	-	0		3	16	
		2-66	53	-	0		22	312	
		12-65	23	-	4		17	32	